= Gesch. 691

H. hydr. 24 L

# MEMOIR

UPON THE

# ILLUMINATION AND BEACONAGE

OF THE

# COASTS OF FRANCE,

BY

M. LÉONCE REYNAUD,

INSPECTOR GENERAL OF BRIDGES AND ROADS, DIRECTOR OF THE LIGHT AND BUOY SERVICE, ETC.

TRANSLATED, FOR THE USE OF THE LIGHT-HOUSE BOARD OF THE UNITED STATES,

BY

**PETER C. HAINS, Major of Engineers, U. S. A.,**

ENGINEER-SECRETARY OF THE LIGHT-HOUSE BOARD.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1876.

BIBLIOTHECA
REGIA
MONACENSIS

# NOTE.

Chapters I and II of Part First and part of Chapter II of Part Second of this Memoir were translated by Rear-Admiral Thornton A. Jenkins, U. S. Navy, Naval Secretary of the Light-house Board, in 1871. A portion of his work, with his consent and approbation, has been made use of in preparing the present volume, but the entire work has been re-translated and revised.

A translation of the entire Memoir proper is now presented, the only parts omitted being Chapter IV of Part First, (a list of lights on the coast of France on January 1, 1864,) and Chapter III of Part Second, (a list of buoys and beacons on the coast of France, January 1, 1864,) and certain documents which form a sort of appendix to the original volume and which were not deemed necessary to be included.

It is proper to remark, also, that document VII, instructions for the service of lenticular lights, is not the same as document VII in the original work. The recent introduction of mineral oil in the Light-house Service of France rendered so many modifications in the original instructions necessary, that a new set were prepared and issued. The latter are given in this translation.

# INTRODUCTION.

This Memoir has been prepared by order of His Excellency the Minister of Agriculture and Public Works, and I do not desire that its publication should cause more credit to be given than belongs to me.

I therefore deem it my duty to call attention to the fact that the lenticular system was invented by Augustin Fresnel; that the present organization of the Light-house Service is due in all fundamental respects to the worthy brother of that illustrious savant; and that the judicious system of our seacoast illumination was worked out by the Commission of Lights, (Commission des Phares.)

Besides, the task which devolved upon me, when I had the honor of being called to the direction of the Light-house Service, has been lightened by the valuable co-operation of others. The Engineers of the maritime Departments directed with their habitual devotion, and with entire success, works which were sometimes attended with danger, and were often difficult of execution; and the Engineers who have been successively associated with me in the Central Service, Messrs. Degrand and Allard, have given me valuable aid in studying new designs of apparatus, and in the numerous experiments which will be found recorded in this work.

I must not omit to add, that the Department of Public Works, appreciating fully the great importance and usefulness of the aids to navigation on our coasts, both as regards the general interests of humanity and the development of the naval and commercial strength of the nation, has always approved the recommendations of the Commission of Lights, encouraged promising innovations, and assisted in the great enterprise which is now nearly completed.

L. REYNAUD.

NOVEMBER, 1864.

# TABLE OF CONTENTS.

## PART I.—ILLUMINATION.

### CHAPTER I.

### GENERAL ARRANGEMENTS.

#### I. DISTRIBUTION OF LIGHTS.

Positions assigned to light-houses of the various orders.
Necessity for distinguishing lights.
General principles.
Exceptional cases.

#### II. CHARACTERISTIC DISTINCTIONS OF LIGHTS.

Characteristics adopted by the Commission of Lights in 1825.
New characteristics.
Coloring.

#### III. RANGES OF LIGHTS.

Luminous ranges: in vacuum; in the atmosphere.
Formula for luminous ranges.
Experiments relative to the determination of the coefficients.
Expressions for transparency of the atmosphere.
Curves of ranges.
Determination of ranges for the different apparatus in three conditions of atmospheric transparency.
Representation of luminous intensities and corresponding ranges.
Geographical ranges.
Atmospheric refraction.
Formula for geographical ranges.
Table of ranges corresponding to various heights of the luminous focus, and of the observer above the level of the sea.

### IV. RELATIVE POSITIONS OF ASSOCIATED LIGHTS.

Object of grouping lights.
Irradiation.
Effects of near-sightedness.
Angles of blending of lights.
Influence of the state of the atmosphere.
Multiple lights constituting a distinctive characteristic.
Their separation.
Positions to give them according to the amplitude of the angular space they are to light.
Leading lights.
Minimum of the angle under which they should be seen.
Experiments.
Empirical formula.
Examples.

---

## CHAPTER II.

## ILLUMINATING APPARATUS.

### I. CATOPTRIC APPARATUS.

Their invention by Teulère.
The present catoptric apparatus.
Parabolic reflectors of one nappe.
Direction of the reflected rays.
Distribution of the rays in a horizontal plane.
Circumstances under which reflectors may be employed with advantage.
Apparatus for a floating light, fixed, with eclipses.
Apparatus of the light at Pontaillac.
Sidereal apparatus.
Manner of making and repairing reflectors.

### II. DIOPTRIC APPARATUS.

Their invention by Augustin Fresnel.
Arrangement of the lenses.
Height of the lenses.
Arrangements relative to the rays passing out above and below the lenticular drum.
Catadioptric rings.
Spherical reflectors.
Dimensions and intensities of the flames.
Orders of lights.
Dimensions of apparatus.
Distribution of the luminous rays.
Direction to give to the luminous beam.
Table of the inclinations of tangents to the surface of the sea.
Position to assign to the flame in an apparatus of the 1st order.
Form of a vertical section of a luminous beam.

Modifications to be introduced in the apparatus on account of its height.
Variations of luminous intensity with the distance.
Position of the flame in apparatus of the 2d, 3d, and 4th orders.
General arrangements of the apparatus.
Apparatus for an electric light.
Apparatus for oil of schist or petroleum.
Luminous intensities of the various parts of lenticular apparatus.
Manner of making lenses.

### III. COMPARISON OF THE TWO SYSTEMS.

Superiority of the dioptric apparatus.
Expression for the useful effect of an illuminating apparatus.
Comparison of apparatus of various orders, according to each system.

### IV. COLORED LIGHTS.

Experiments with colored lights.
Graphic expression of the results.
Action of some fogs.
Superiority of red over all other colors.
Coefficient for reduction adopted in the Light-house Service.
Arrangements of the apparatus for colored lights.

### V. TYPES OF APPARATUS.

Apparatus of the 1st order: for fixed light; for fixed light varied by flashes; for light with eclipses every minute, every 30 seconds, every 20 seconds, and less.
Apparatus of the 2d order: for fixed light; for light with eclipses.
Apparatus of the 3d order: for fixed light; for fixed light varied by flashes, with or without eclipses; for light with eclipses.
Apparatus of 3d order, (small model.)
Apparatus of the 4th order.
Apparatus for floating lights: for fixed light; for light with eclipses.
Revolving machinery.
Frames.
Lanterns.

### VI. COMBUSTIBLES.

Fatty oils.
Lamps; number and diameter of wicks.
Wicks.
Glass chimneys.
Oils of petroleum or of schist; their economic value.
Gaseous combustibles.
Electric light.
Magneto-electric machine.
Lamp or regulator.
Carbon points.
Luminous intensity.
Application of the electric light for the illumination of one of the light-houses at La Hève.
Comparative advantages of the electric light.

## CHAPTER III.

### LIGHT-HOUSE STRUCTURES.

#### I. ARRANGEMENTS.

Light-houses of antiquity.
Light-house of Genoa.
Light-house of Cordouan.
Modern light-houses: spirit in which they are conceived; their towers, stairways, apparatus-rooms, store-rooms, keepers' apartments, &c.
Frame light-houses.
Iron light-houses.

#### II. TYPES OF STRUCTURES.

Light-houses of La Hève, Héaux de Bréhat, Calais, Baleines, Porto Vecchio, Point Grave, Haut Banc du Nord, Triagoz, Kermorvan, Pontaillac, New Caledonia, Walde.
Light-houses of the 4th order, with keepers' dwellings.
Isolated lights of low orders.
Ruytingen light-vessel.

---

## CHAPTER IV.

List of lights on the coasts of France on January 1, 1864, (omitted.)

# PART II.—BEACONAGE.

## CHAPTER I.

### I. DAY-MARKS.

Object, dimensions, forms, and color of day-marks.
Experiments relative thereto.

### II. BEACONS.

Beacons—of wood, of iron, of masonry.
Bell-beacons.

### III. BUOYS.

Buoys—of wood, of plate-iron.
Types of buoys.
Buoy appendages.
Mode of anchoring.
Chains and anchors.

### IV. COLOR OF BEACONS AND BUOYS.

Coloring and numbering of beacons and buoys.

## CHAPTER II.

## SIGNALS.

### I. TIDE-SIGNALS.

Complete system.
Modifications of which it is susceptible.
Dimensions and separation of the balls.
Night signals.
Table of signals.

### II. FOG-SIGNALS.

Various instruments.
Experiments.
Bells.
Reflectors.
Manner of distinguishing.

# CHAPTER III.

List of beacons and buoys on the coasts of France on January 1, 1864, (omitted.)

---

DOCUMENTS.

I.

Report containing a full account of the system adopted by the Commission of Lights for lighting the coasts of France, and a list of the successive members of this Commission, (omitted.)

II.

Memoir on a new system of illumination of light-houses, by Augustin Fresnel, read before the Academy of Sciences July 29, 1822.

III.

Calculation of the elements of the lenticular apparatus, by Mr. E. Allard, engineer-in-chief of bridges and roads, (omitted.)

IV.

List of pieces of illuminating apparatus and lanterns, (omitted.)

V.

Detailed estimate of the annual cost of illuminating light-houses, (omitted.)

VI.

Conditions of contract for furnishing oil of colza, (omitted.)

VII.

Instructions for the service of the lenticular lights, (phares.)

VIII.

Instructions for the service of (fanaux) lights of the smaller orders.

IX.

Instructions for the service of floating lights.

X.

Rules for light-keepers.

XI.

Records and forms for reports, &c., in use, (omitted.)

# LIST OF PLATES.

| Numbers of the Figures. | Numbers of the Plates and Descriptions of the Figures. |
|---|---|
| | ATE 1. |
| 1 to 17 | Distribution, range, form, and intensity of the luminous rays emanating from the different lenticular apparatus. |
| | PLATE 2. |
| 1 and 2 | Curves, showing how the luminous rays vary with the transparency of the atmosphere. |
| | PLATE 3. |
| 1 to 3 | Profiles of lenticular apparatus of the 1st, 2d, and 3d orders. |
| 4 | Profile of a lenticular apparatus of the 3d order, (small model.) |
| 5 and 6 | Profiles of lenticular apparatus of the 4th order. |
| 7 | Profile of a lenticular apparatus for a mineral oil lamp. |
| 8 to 11 | Profiles of lenses and vertical elements of apparatus of the three largest orders. |
| | PLATE 4. |
| 1 | Plan of a lantern and of an apparatus of the 1st order - - { A, eclipses every minute. B, fixed light varied by flashes. C, a fixed light. |
| 2 | Plan of a lantern and of an apparatus of the 2d order - - { A, eclipses every 30 seconds. B, a fixed light. |
| 3 | Plan of a lantern and of an apparatus of the 3d order - - { A, a fixed light. B, a fixed light varied by flashes. |
| | PLATE 5. |
| 1 and 2 | Plan and elevation of an apparatus of the 1st order, (fixed light.) |
| 3 and 4 | Plan and elevation of an apparatus of the 1st order, with eclipses every minute. |
| 5 and 6 | Plan and elevation of an apparatus of the 1st order, with eclipses every 20 seconds, with alternate white and red flashes. |
| 7 to 9 | Plan and elevation of an apparatus of the 3d order, fixed white, varied at intervals of 20 seconds by alternate red and green flashes. |
| 10 and 11 | Plan and elevation of an apparatus of the 3d order, (small model,) fixed light varied by flashes. |
| 12 and 13 | Plan and elevation of an apparatus of the 3d order, with eclipses every minute. |
| | PLATE 6. |
| 1 | Section of a lantern and an apparatus of the 1st order; fixed light to the right; light varied by flashes to the left. |
| 2 | Elevation of a panel of a fixed-light apparatus. |
| 3 | Elevation of a lens with vertical elements. |
| | PLATE 7. |
| 1 | Section of a lantern and an apparatus of the 1st order, with eclipses every minute. |
| 2 | Elevation of one of the panels of that apparatus. |

| Numbers of the Figures. | Numbers of the Plates and Descriptions of the Figures. |
|---|---|
| 3 | Elevation of a panel of an apparatus of the 1st order, with eclipses every 30 seconds. |
| 4 | Elevation of an apparatus of the same order, with eclipses every 20 seconds and less. |
| | Plate 8. |
| 1 | Section of a lantern and an apparatus of the 2d order; fixed light to the right; eclipse light every 30 seconds to the left. |
| 2 | Elevation of a panel of a fixed light of that apparatus. |
| 3 | Elevation of a panel of an apparatus of the 2d order, with eclipses every 30 seconds. |
| | Plate 9. |
| 1 | Section of a lantern and of an apparatus of the 3d order; light varied by flashes to the right; fixed light to the left. |
| 2 | Elevation of one of the panels of the fixed light. |
| 3 | Elevation of a vertical-element lens. |
| | Plate 10. |
| 1 and 2 | Plan and section of a lantern and an apparatus of the 3d order, (small model;) fixed light, varied by red flashes every 20 seconds. |
| 3 | Elevation of one of the panels of that apparatus. |
| | Plate 11. |
| 1 and 2 | Plan and section of a lantern and apparatus of the 3d order, (small model;) fixed light varied by flashes. |
| | Plate 12. |
| 1 and 2 | Plan and section of an apparatus of the 4th order; fixed light; (large model.) |
| 3 and 4 | Plan and section of an apparatus of the 4th order; fixed light; (small model.) |
| 5 and 6 | Plan and section of an apparatus of the 4th order, of molded glass, with movable lantern. |
| 7 and 8 | Elevation and section of a lens apparatus of molded glass for range lights. |
| 9 and 10 | Elevation and section of a lens apparatus of polished glass for range lights. |
| 11 to 13 | Plan, front elevation, and side elevation of a reflector on its stand. |
| 14 and 15 | Plan and elevation of a "sideral" apparatus placed in a movable lantern. |
| | Plate 13. |
| 1 to 4 | Elevation, section, and plan of an apparatus for a floating fixed light. |
| 5 to 7 | Details of one of the reflectors. |
| | Plate 14. |
| 1 to 3 | Sections and plans of a floating eclipse-light. |
| 4 to 10 | Details of the system of transmitting the motion. |
| | Plate 15. |
| 1 and 2 | Plan, section, and elevation of a lamp burner of the 1st order. |
| 3 and 4 | Plan, section, and elevation of a lamp burner of the 2d order. |

| Numbers of the Figures. | Numbers of the Plates and Descriptions of the Figures. |
|---|---|
| 5 and 6 | Plan, section, and elevation of a lamp burner of the 3d order. |
| 7 and 8 | Plan, section, and elevation of a lamp burner of the 4th order. |
| 9 and 10 | Plan, section, and elevation of a lamp burner for mineral oils. |
| | Plate 16. |
| 1 to 3 | Plan of the ground floor, and the first and second stories of the Cordouan light-house. |
| 4 to 6 | Sectional plans of the same building taken, respectively, at the height of the ninth step of the grand stairway of the watch-room, and of the lantern. |
| | Plate 17. |
| | Vertical section of the Cordouan light-house. |
| | Plate 18. |
| | Elevation of the Cordouan light-house. |
| | Plate 19. |
| 1, 2, and 3 | Elevation and section of the light-house towers of La Hêve, (Havre,) and plan of the watch-room of the lantern. |
| 4 and 5 | Plan and elevation of the two towers, and their dependencies. |
| | Plate 20. |
| 1 and 2 | Elevation and vertical section of the light-house tower of Bréhat. |
| 3 to 6 | Sectional plans of the same edifice taken respectively at the heights of A B, C D, E F, and G H. |
| | Plate 21. |
| 1 and 2 | Elevation and vertical section of the light-house tower at Calais, France. |
| 3 to 5 | Sectional plans of the same building taken respectively at the heights of A B, C D, and E F. |
| | Plate 22. |
| 1 | Vertical section of the light-house tower of Baleines, coast of France. |
| 2 to 4 | Sectional plans of the same building taken respectively at the heights of A B, C D, and E F. |
| 5 to 8 | Details of the stairway-opening in the upper arch. |
| | Plate 23. |
| 1 and 2 | Plan of the ground-floor and elevation of the light-house tower of the Baleines. |
| | Plate 24. |
| 1 to 4 | Elevation, section, and plan of the light-house tower at Porto Vecchio. |
| 5 | Plan of the ground-floor of the light-house tower of Breac'h, (Ile d'Ouessant.) |

| Numbers of the Figures. | Numbers of the Plates and Descriptions of the Figures. |
|---|---|
| | Plate 25. |
| 1 and 2 | Elevation and section of the light-house tower of Haut-Banc du Nord, (Ile de Ré.) |
| 3 to 5 | Sectional plans of the same edifice taken respectively at the heights of C D, E F, and G H. |
| | Plate 26. |
| 1 and 2 | Elevation and vertical section of the light-house tower of Point of Grave. |
| 3 to 5 | Sectional plans of the same edifice taken respectively at the heights of A B, C D, and E F. |
| | Plate 27. |
| 1 | Principal elevation of the light-house tower of the Triagoz. |
| 2 to 4 | Rear elevation, section, and ground-plan of the same building. |
| | Plate 28. |
| 1 to 3 | Elevation and sections of the light-house tower of Kermorvan. |
| 4 to 8 | Sectional plans of the same building taken respectively at the heights of E F, G H, K L, M N, and O P Q R. |
| | Plate 29. |
| 1 and 2 | Plan and elevation of the light-house tower of Pontaillac. |
| 3 and 4 | Details of the upper part of the building. |
| | Plate 30. |
| 1 and 2 | Elevation and section of the light-house tower of New Caledonia. |
| 3 to 5 | Sectional plans of the same building taken respectively at the heights of E F, G H, and I J. |
| | Plate 31. |
| 1 to 3 | Plans and elevation of the light-house tower of Walde. |
| 4 to 12 | Details of the principal means of fastening the various parts of that building. |
| | Plate 32. |
| 1 to 4 | Elevations, section, and ground-plan of a type of light-tower for lights of the 4th order, with dwelling for the keeper. |
| 5 to 7 | Elevation, section, and ground-plan of a type of light-tower for lights of the 4th order, with dwelling for the keeper, constructed of wrought-iron. |
| 8 to 10 | Elevations and plan of a type of dwelling for light-keepers, with suspended lanterns. |
| | Plate 33. |
| 1 to 4 | Elevation, section, and plans of a type of small tower for harbor lights. |
| 5 to 8 | Elevation, section, and plans of a type of small tower for harbor lights, constructed of wrought-iron. |
| 9 to 11 | Elevation, section, and plan of a wooden scaffolding for a suspension light. |
| 12 and 13 | Section and lateral elevation of a candelabra, constructed of iron, for a suspension light. |
| 14 and 15 | Elevation and section of a candelabra of iron for a suspension light. |

| Numbers of the Figures. | Numbers of the Plates and Descriptions of the Figures. |
|---|---|
| | Plate 34. |
| 1 | Half-breadth and half-deck plan of the light-vessel of Ruytingen. |
| 2 | Sheer plan of the vessel. |
| 3 | Transverse elevations forward and aft. |
| 4 | Side elevation of the vessel with the lantern down. |
| | Plate 35. |
| 1 | Spar-deck plan of the light-vessel of Ruytingen. |
| 2 and 3 | Longitudinal and midship cross-sections of the vessel. |
| | Plate 36. |
| 1 to 3 | Plan and elevation of the beacon constructed of wood at Biscarosse. |
| 4 | Elevation of the beacon at Cape Bréton. |
| 5 | Arrangement for a distinguishing mark of a beacon. |
| 6 and 7 | Elevations of a small wooden beacon. |
| 8 to 10 | Plan, elevation, and details of the iron-pile beacon of Antioch. |
| 11 | Type of a masonry tower beacon. |
| 12 and 13 | Type of the small beacon towers in the Mediterranean. |
| | Plate 37. |
| 1 and 2 | Elevation, section, and plan of wooden buoy and spindle. |
| 3 and 4 | Elevation, section, and plan of wooden mooring buoy. |
| 5 and 6 | Elevation, section, and plan of small-size buoys. |
| 7 and 8 | Elevation, section, and plan of a wooden buoy with perch and mark. |
| 9 to 11 | Plan, elevation, and section of a small wooden mooring buoy. |
| 12 to 15 | Plans and sections of cast-iron anchors. |
| | Plate 38. |
| 1 and 2 | Elevation, section, and plan of an iron buoy, (Model No. 1.) |
| 4 | Elevation and section of a small iron buoy, (Model No. 3.) |
| 5 and 6 | Elevation, section, and plan of iron buoy with bell and mirrors. |
| 3 | Detail of the ballast of that buoy. |
| 7 | Elevation and section of an iron mooring buoy. |
| 9 | Elevation and section of one of the large mooring buoys of the Maritime Transportation Company of France. |
| 8 | Section of an anchor for a mooring buoy in the basin of St. Nazaire, France. |
| 10 | View of a mushroom anchor. |
| 11 and 12 | Distinctive marks for iron buoys. |
| | Plate 39. |
| 1 to 3 | Plans, section, and elevation of a bell-boat buoy. |

# MEMOIR

UPON THE

# ILLUMINATION AND BEACONAGE

OF THE

# COASTS OF FRANCE.

## PART I.—ILLUMINATION.

### CHAPTER I.

### GENERAL FEATURES.

#### I. DISTRIBUTION OF LIGHTS.

The entrances to ports and the mouths of navigable streams were for a long time regarded as the only places at which lights were needed, and the chief object was to give as great range as possible to the lights which marked them. This is no longer the case; the requirements of navigation having become much greater, they had to be more fully met; in becoming more fully developed, the illumination of maritime coasts became based upon different laws, and it is now considered that the greater number of these points need only be provided with lights of secondary importance, while the principal lights are assigned to positions where they will be of most service.

As it is in approaching the coast that the most serious dangers to navigation exist, it is, as a natural consequence, of the greatest importance that the coast line should be first indicated to the approaching mariner. This line of seacoast presents a series of headlands more or less salient, which may be considered as the angles of a polygon, inclosing within it all outlying dangers. A light is placed on each of these headlands or capes, so that the mariner may be warned of his approach to land at as great a distance as the elevation of the light and the power of the illuminating apparatus will allow; the distances between the lights being so regulated with reference to the distances at which they can be seen, that it is impossible to come near the coast in clear weather without seeing at least one of them.

Those lights, which are specially designed to give warning of approach to the coast line, are known as LAND-FALL LIGHTS. They are of the *first order*, and are visible at the greatest distance.

After having warned the mariner of his proximity to the coast, and indicated to him the proper course to steer, it then becomes necessary to provide the means of proceeding safely to the place for which he is bound. For this purpose recourse is had to lights of less power. In the sea space of greater or less extent, (and more or less open,) embraced between two first-order lights, there are points, such as secondary capes, islands, rocks, reefs, and sand-

banks, the position of which the mariner should know, and channels where guide lights are useful; these places are marked by lights the powers of which are proportionate to the distances at which they should be seen. They differ from those of the first order not in intensity alone; in some of them the luminous rays are concentrated within a very small angular space, while the former illuminate the entire sea-horizon which they command.

Finally, the course being thus marked out to a point near the harbor at which the voyage is to end, it suffices to place a small light on each of the piers, or on one of them only, to point out the entrance to the channel. Some of these small lights belonging to tidal harbors are not exhibited until the tide has reached a certain determined height. Generally, when harbors of this kind are marked by two lights, one is used as a *tide light*, while the other is permanent, always marking the locality.

During thick weather, when the distances at which first-order lights can be seen are considerably reduced, the secondary lights help to fill up the gaps in the primary illumination, and thus maintain its continuity, or at least diminish in a great degree the extent of the unlighted portions of the coast.

The range (or distance at which they may be seen) assigned to first-order lights varies from 18 to 27 nautical miles, according to their character. That of other lights varies much more, being from 2 to 20 miles. These latter lights are divided into three orders, according to the quantity of light emitted from the focus of the apparatus.

These lights, if greatly multiplied, might lead to fatal mistakes were it not that means have been devised for varying their appearances so that one is not likely to be mistaken for another. These means could not be applied when the light was produced by the combustion of wood or coal, except to the extent of grouping several lights at the same point, which method was limited in its application and very expensive. But the invention of parabolic reflectors with double-current-of-air lamps, and afterward the still more valuable invention of Augustin Fresnel, enable the characteristics to be varied all that is necessary, and at the same time the power of the lights to be vastly increased.

It is of the greatest importance that the lights of the first order, and those which, on some particular points, fulfill the necessary requirements of great *land-fall lights*, should appear very different from each other, so that the mariner may be duly apprised of his position and enabled to rectify any errors of reckoning before he shall have approached the coast too near for safety; but it is not necessary that each light should have a special characteristic; it will suffice that the distances between those of the same characteristic should exceed any error of position, which might result under ordinary circumstances of navigation. To fix a limit to that error is doubtless by no means easy; nevertheless, the Commission of Lights judged that a navigator ought not to be more than 80 miles in error of his true position, except under extraordinary circumstances, and after such a series of events as should make him extremely cautious in approaching the land. Warned of his approach by seeing a light, if he has the least doubt as to his position he should keep well off the land during the night.

It may be remarked also, that a mistake which might be easily made when but one light is in sight, would be instantly recognized when one or more of the secondary lights on the same coast appear, on account of the diversity in their characteristics, number, and relative positions. Under such circumstances we may sometimes keep within the limit just referred to. For example, the first-order fixed lights of the Isle of Groix and the Isle of Yeu are only 72 miles apart, but the first one cannot be seen on the same bearing as the second, without seeing, at the same time, either the fixed light varied by flashes on the island of Penfret, or the eclipse light showing a flash once every minute on Belle-Isle-en-Mer, so there is no possibility of mistake.

For similar reasons the light at Carteret has the same characteristic as the one on Cape Fréhel, although they are but 46 miles apart.

It is thus seen that the general principles upon which the illumination of the coast of France is based may be summed up as follows:

Warning of approach to the coast line is given at as great a distance as is necessary, by establishing lights sufficiently diversified in appearance to properly indicate their respective positions, and so placed that the mariner cannot make the land in clear weather without bringing at least one light into view; then, between these are established lights of varied characteristics, with ranges in proportion to the distances at which they should be seen; these serve as guides to the entrances of ports.

These principles were set forth for the first time in the report presented to the Commission of Lights by Admiral Rossel, and approved by the Commission September 9, 1825. They have never been lost sight of; but it will be readily understood that it has not always been possible to apply them rigorously. A coast line of great extent is so varied in its character that no absolute rule could be rigidly adhered to. Thus, beyond the sides of the ideal polygon, at the angles of which the first-order lights are placed, there may exist an islet, the head of a rock, or a sand-bank which it is necessary to mark, and a light of secondary importance is used for the purpose. Thus, on our channel coast, for example, the group of the Seven Isles is situated to seaward of the line which connects the first-order lights at the Héaux de Bréhat and the Isle de Bas, and a light of the third order is placed there. It is the same with Isle Vierge, between the lights at Isle de Bas and Ouessant.

Sometimes, too, the configuration of the coast line is such that two first-order lights cannot be placed sufficiently near to each other for their arcs of illumination to cross, and in such cases the gap is filled up by a secondary light. A case of this kind occurs between the lights of La Hève and Barfleur, which are separated by a deep bay illuminated by a third-order light on Point Ver; the same thing occurs between the lights of Belle-Isle and Isle of Yeu, where the Pilier light is located, and between the lights of Agde and Faraman, where the light at Aigues-Mortes illuminates the interval.

It may also happen that a light without being of the land-fall class should, however, have the range of one of the first order. The light of Fatouville, at the mouth of the Seine, is an example; the object for which it was established and the configuration of the coast line at that point rendering it necessary to place it at such a distance inland, that a less powerful intensity would not have answered the purpose.

Lastly, when a cape which, from its position, would naturally be marked by a first-order light is not very prominent and is situated between points which it is necessary to light, such as entrances to ports of a certain degree of importance, there may be an advantage in leaving it unlighted, and erecting a land-fall light upon one or both of those minor points. For example, Cape Antifer, between Fécamp and Havre, is not lighted, and first-order seacoast lights are placed on the heights which command the entrances to these ports. The low cape between Dunkerque and Gravelines, which has been treated in the same way, may be cited as another example.

Further, it will be sufficient to examine the map and the list of lights to judge how these general principles have been carried out, and what the geographical circumstances are which have sometimes occasioned a slight departure from them.

## II. CHARACTERISTICS OF LIGHTS.

The programme agreed upon by the Commission of Lights in 1825 provided only for three different characteristics for first-order lights: *the fixed light, the light with eclipses every minute, and the light with eclipses every half minute.** A fixed light was always to be placed between two eclipse lights of different intervals. Lights of the same appearance would thus be separated as much as was thought to be necessary.

Experience has shown however, that navigators of merchant-vessels do not always pay sufficient attention to the differences in the intervals between eclipses in the lights of which we have spoken. On the other hand, the number of lights has increased so greatly beyond

* These eclipse lights are similar to those now designated as "flashing" in the United States Light-house Service.—P. C. H.

what was anticipated in 1825 that it has been found necessary to introduce a much larger number of distinctions.

One distinction which may be said to belong to the infancy of the art, and which was adopted toward the close of the last century for one of our most important land-falls—that of Havre—was continued exceptionally at this point by the programme of 1825: It consists in the exhibition of two first-order fixed lights side by side, at such a distance apart that they do not seem to blend even when viewed from the limit of their range, and yet are always recognized as constituting a group. This distinction is, without doubt, objectionable on account of the expense, which is nearly double both for construction and maintenance; but it has the advantage of being very well-marked, and is highly appreciated by mariners. Several examples of this class are found on the coasts of England. This distinction has been recently made use of in France in lighting the low dangerous shore near the mouth of the Canche, and also on the coast of the Gulf of Gascony in the interval between the light of Cordouan and that of Arcachon Basin.

Another distinction, which was at first used only for apparatus of the second and third orders, has since been applied to lights of the first order; that is, the fixed light varied by successive flashes, accompanied by eclipses once in every three minutes and once in every four minutes—that is to say, having intervals between the flashes long enough to prevent the lights from being mistaken for the ordinary eclipse light. This distinction has been selected for the lights at Calais, Isle de Sein, Porquerolles, Sanguinaires, and Porto Vécchio, in order to prevent their being mistaken for others in the same vicinity.

By pursuing an opposite course we can also give an eclipse light a characteristic no less marked; that is to say, we can greatly increase the rapidity with which the flashes succeed each other. The Commission of Lights has adopted recently, for a first-order light to be placed on a point where it is important that it should not be mistaken for another, an apparatus in which the interval between the eclipses will be but one and a half seconds, thus producing a sort of scintillation. This is called a *scintillating light*. No fixed light is seen during the intervals between the flashes.

Lastly, colored lights have been introduced as distinctive characteristics. This mode of distinguishing lights was condemned at first in the most emphatic manner; and it certainly has disadvantages which should make us use it with great caution. It greatly reduces the intensity of the light, and atmospheric conditions sometimes cause lights to assume a color which might lead to mistakes. But it has been found that these phenomena are not of so grave a character as had been supposed; and the Commission of Lights, yielding to the solicitations of navigators, permitted at first the introduction of the red color as a means of distinguishing the lights of the lowest order, and afterward introduced it even for lights of the first order. It also approved green lights in certain exceptional cases. The subject is one of such importance that it seems proper to make known the reasons upon which these decisions were based.

There are only three colors sufficiently decided to be used in connection with white for distinguishing-lights—the red, green, and blue. These colors are produced by passing the rays of light emanating from the luminous focus through glass of suitable colors; and photometric experiments, made under ordinary circumstances—that is to say, at short distances—establish the fact that well-marked tints cause a loss of light which may reach even 95 per cent. Of all these colors, red is the most distinct for an equal absorption of the luminous rays; but this is not its only merit, considered in regard to maritime illumination; it possesses another of great importance, which has been proved by experiments which will be hereafter referred to when we come to consider the question of "Arrangement of Apparatus," namely: that with equal intensity, the red can be seen farther than the white light. If two lights, one red and the other white, appear to be of about equal intensity as estimated by the usual photometric process, the brilliancy of the red light will be greater than that of the white when they are both observed at great distances; and this effect will be still more marked as the distance from them increases. The white light will become invisible

before the other. This phenomenon is especially marked in certain states of the atmosphere; and that is readily understood, since fog generally has a tendency to make a white light appear red; from which it may be inferred that the red rays of the spectrum are transmitted through it more readily than the others. Some heavy fogs allow all the luminous rays to pass equally, and only have the effect of diminishing their intensity; they dim the lights without coloring them.

Observations made at the light of Pontaillac, at the mouth of the Gironde, may be cited in illustration of this subject. This apparatus is so arranged as to produce a light which is alternately red and white, without eclipses. Measured by the photometer, at about 8 meters* for the distance of the lights, the intensities were estimated to be about 1100 carcel burners† for the white light, and about 700 burners for the red. When near the light-house the white light appeared more brilliant than the red, but farther off they appeared to be equal; and still farther yet the red was sometimes brighter than the white light. Some navigators have even affirmed that during foggy weather they have seen the red flashes farther than the white ones. The distances at which these phenomena are produced vary with the state of the atmosphere.

It is seen, then, that the loss of light caused by coloring it red is not so great as had been previously inferred from experiments made at short distances, and that the red light becomes impaired much less rapidly than the white light during ordinary thick weather, at which time it is highly important to have brilliant lights.

The reverse of the above is true with reference to the green and blue lights, as, indeed, might easily have been foreseen. They diminish in intensity much more rapidly in proportion than the white as the distance increases, and still more so as the atmosphere becomes thicker. This subject will be again considered.

The colorations produced by the atmosphere are well known. It has been observed that during foggy weather white lights usually become red, green become white, and blue lights disappear or change to so pale a violet tint as to be mistaken for white. These phenomena should receive careful consideration, but their importance is not so great when, instead of a single isolated light, there are two of different colors in view, and especially when one of them is red and the other white. If the white light appears reddish, the red one becomes more intensely red, and thus its characteristic is preserved. It would not be the same however, if green were substituted for red; they would still be distinguishable from each other, but instead of seeing them white and green they would appear dull red and dull white, and to determine the true colors would require an acuteness of vision which is seldom found. In view of the above facts the red color appears to be superior to all others.

Such are the considerations which caused the introduction of color as a distinction in light-house illumination, and the almost exclusive use of red for that purpose. These considerations also determined the mode of employing color.

Red fixed lights have been placed only at points where one or more fixed white lights are seen at the same time, so that their true color cannot be mistaken. No *fixed light* of the first order has, however, been colored, as it is important that the over-sea voyager should have no doubt as to the true color of the single light which he first sees in approaching land.

Fixed lights of short range are often colored red when it is feared they might be confounded with the street-lamps or with lights in dwellings near by.

When piers at the entrance of a port are each marked by a light, one is usually red and the other white.

* A meter = 39.3685 inches.
A kilometer = 3280.71 feet = about .62 of a mile.
A gramme = 15.432 grains.
A kilogramme = 2.205 pounds avoirdupois.
A franc = about 19 cents.

† The carcel burner is the unit for the measurement of the intensity of light adopted in the Light-house Service, as will be seen further on.

The same rule applies with reference to leading lights; it is necessary to diversify them when their positions are such that the most distant does not always appear to the navigator above the other, and one is almost always colored red. Recourse is even sometimes had to green, where there is danger of confusion with a neighboring group.

Red is also used for lights of the first order when they are not fixed. It is evident, indeed, that there can be no disadvantage in coloring the flashes of the flashing lights already spoken of when these flashes are not used for increasing the range, but merely to give it a distinctive character. Instead of varying a fixed white light at intervals of three or four minutes by a period of much greater luminous intensity, it may be varied by changes to red. Color is substituted for the flash, and it always preserves its distinctive characteristic for the reason that it immediately succeeds white.

A similar arrangement has been used for eclipse lights. The flashes of these lights are colored, some red, others white; sometimes the colors alternate, and sometimes two white flashes are followed by a red one.

It will be seen further on that the apparatus is then arranged in such a way as to receive more of the luminous rays upon the colored panels than upon the others.

Finally, a new distinction, based upon the introduction of two colors, has been recently adopted for a third-order light not required to be seen at a great distance, and which might occasion mistakes if not very sharply distinguished from its immediate neighbors. This light is white, and becomes alternately red and green for some moments at regular intervals of twenty seconds, without any eclipses between the different luminous apparitions. When there is fog the green flash will be dimmed more or less and eclipses might then result at a certain distance; but navigators are not ignorant of the effects such a state of atmosphere produces, and always recognize the light. Some apparatus, similar in general arrangement, vary the white light by red flashes only. Thus in the present state of the Light-house Service the *land-fall*, or *first-order* lights of France, have nine different distinctive characteristics, viz:

WHITE LIGHTS.

1. Fixed light.
2. Light with eclipses once every minute.
3. Light with eclipses every half minute.
4. Scintillating light.
5. Fixed light varied by flashes.
6. Two fixed lights.

COLORED LIGHTS.

7. Fixed white light varied by red flashes.
8. Eclipse light with alternate red and white flashes.
9. Eclipse light with two white flashes succeeded by a red flash.

It would be easy to obtain a greater number of distinctions by means of other combinations of the same elements, but, so far, there has been no necessity for them.

The same distinctions, and others besides, such as the fixed red light before referred to, the red light with eclipses, and the alternate white and red light with or without eclipses, and the light alternately white, red, and green, may be used for apparatus of the second and third orders.

As to lights of the fourth order, they are mostly fixed, and are distinguished by either position or color. They are not generally characterized by eclipses, for the reason that the navigator is so near the shore at the time when they serve as his guides that it is important for him to keep them always in view.

The arrangements which produce the different characters of lights will be described when the subject of illuminating apparatus is reached.

## III. RANGES OF LIGHTS.

The distance at which a light may be seen depends upon its intensity and its height above the level of the sea. We thus have the *luminous range* and the *geographical range.* We will examine successively the considerations on which their values are based.

### LUMINOUS RANGES.

The power of illuminating apparatus is determined by measurements with a photometer, the unit of measure being the light of a carcel lamp, the burner of which has a diameter of .02 of a meter and consumes 40 grammes of colza oil per hour.

If the lights transmitted their rays through a vacuum the ranges would be proportional to the square roots of their intensities, and it would suffice to know the distance at which a light of a given power could be seen by a person endowed with ordinary vision to determine the range of a light of different intensity. Thus, admitting that the light produced by a carcel lamp may be seen at the distance of 10 kilometers, it would be concluded that a fixed light of the first order with an intensity equal to 630 carcel burners ought to have a range of 251 kilometers, and that the brightest part of the flash of a light of the same order, with eclipses once every minute, equal to 5075 carcel burners, should be seen 712 kilometers.

But the atmosphere is more or less opaque, which has the effect, in connection with the distance, of weakening the luminous rays, and its action varies between very distant limits. There are some dense fogs that the rays of our most powerful lights can penetrate but a few meters. The ranges, therefore, depend upon the state of the atmosphere, and are actually much less than those which would be deduced from the law just referred to. It is evident, besides, that they also depend upon the acuteness of the observer's vision.

Elements so variable and so difficult to accurately estimate do not enable us to obtain great exactness in the measurements of the ranges, nor to place much confidence in them any way; yet it is desirable, even from a practical point of view, to study the question and subject it to calculation.

Let L represent the luminous intensity of an illuminating apparatus, or the quantity of light sent upon the unit of surface at the unit of distance; the quantity of light emitted by the carcel lamp already mentioned being taken for unity;

$a$, the fraction of light which can just pass through a stratum of atmosphere whose thickness is equal to the unit of distance;

$\lambda$, the smallest quantity of light which the observer could see at the unit of distance in a perfectly transparent atmosphere;

$x$, the range of the illuminating apparatus.

We should then have $\frac{L}{x^2} = \lambda$, if the light was transmitted through a vacuum, and $\frac{L\,a^x}{x^2} = \lambda$, if it were transmitted through the atmosphere.

The values to be given to the coefficients $a$ and $\lambda$ must be determined from experiments.

Bouguer has made observations upon the quantity of light which is emitted from the full moon at different elevations, to determine the diminution caused by a clear calm atmosphere, and the results found led him to assign to $a$ the value of 0.973, the kilometer being the unit of distance.

A series of experiments was undertaken by the engineers of the Light-house Service to determine the values of that coefficient when the weather is more or less foggy, and also the value of $\lambda$. They consisted in observing, under various atmospheric conditions, lights of different but known intensities, and of measuring the distances at which they ceased to be visible to an observer possessing ordinary good sight. The illuminating apparatus were placed

in front of the windows of the central light-house depot, and the observations made from the Champ de Mars. They employed in succession different apparatus, and a lamp or candle, before which was placed a certain number of panes of glass, which absorbed more or less light, the quantity of which had been previously determined.

Two carefully made observations sufficed to give the value of $\lambda$ and that of $a$ at the moment of the experiment; since, in the equations

$$\frac{L' a^{x'}}{x'^2} = \lambda, \quad \frac{L'' a^{x''}}{x''^2} = \lambda,$$

the quantities L′, L″, $x'$, and $x''$, the respective intensities and ranges of the observed lights, are known. But it is easy to see that experiments of that kind are only approximately accurate; they should be multiplied, and confidence given only to the mean values deduced therefrom.

The following table shows the values which have been assigned to L and found for $x$ in the experiments made:

| No. | Date of the experiment. | Kind of illuminating apparatus. | | Values of— L | Values of— $x$ | Values of— $\log. \frac{L}{x^2}$ |
|---|---|---|---|---|---|---|
| | | | | *Burners.* | *Kilom.* | |
| 1 | October 24, 1860 | Candle of an intensity of 0.1 of a burner with— | 13 panes | 0.038 | 0.750 | $\bar{2}.830$ |
| | | | 9 do. | 0.050 | 0.830 | $\bar{2}.861$ |
| | | | 5 do. | 0.070 | 0.950 | $\bar{2}.890$ |
| | | | 1 do. | 0.094 | 1.010 | $\bar{2}.964$ |
| | | Small lamp of an intensity of 0.32 of a burner with— | 15 panes | 0.106 | 1.030 | $\bar{1}.000$ |
| | | | 12 do. | 0.131 | 1.050 | $\bar{1}.075$ |
| | | | 8 do. | 0.176 | 1.130 | $\bar{1}.139$ |
| | | | 4 do. | 0.237 | 1.300 | $\bar{1}.147$ |
| 2 | October 25, 1860 | Candle of an intensity of 0.13 of a burner with— | 22 panes | 0.026 | 0.965 | $\bar{2}.446$ |
| | | | 7 do. | 0.078 | 1.405 | $\bar{2}.597$ |
| 3 | December 24, 1860 | Apparatus in striated glass, (seen below the optical axis) | | 4.000 | 1.200 | 0.444 |
| | | Photophore, (seen below the optical axis) | | 40.000 | 1.600 | 1.194 |
| 4 | January 23, 1861, (from 8 to 9 o'clock.) | Carcel lamp, unity | | 1.000 | 0.330 | 0.963 |
| | | Lamp of 3d order | | 4.400 | 0.380 | 1.484 |
| | | Lamp of 1st order, 23 burners, with 4 panes | | 14.700 | 0.425 | 1.911 |
| | | Lamp of 1st order, 23 burners, with 2 panes | | 17.000 | 0.435 | 1.953 |
| | | Lamp of 1st order, 23 burners, with 1 pane | | 21.000 | 0.445 | 2.026 |
| 5 | January 23, 1861, (after 9 o'clock.) | Lens with fixed light, 1st order | | 300.000 | 0.520 | 3.045 |
| | | Lens with electric light | | 2500.000 | 0.600 | 3.842 |
| 6 | January 29, 1861 | Small lamp | | 0.600 | 0.023 | 3.055 |
| | | Carcel lamp, unity | | 1.000 | 0.025 | 3.204 |
| | | Double-wick lamp | | 3.100 | 0.028 | 3.597 |
| 7 | February 4, 1861 | Robert lamp, with an elevation of flame of— | 33 millimeters | 0.063 | 0.740 | $\bar{1}.061$ |
| | | | 45 do. | 0.100 | 0.870 | $\bar{1}.121$ |
| | | | 55 do. | 0.140 | 0.915 | $\bar{1}.223$ |
| | | | 75 do. | 0.170 | 1.005 | $\bar{1}.226$ |

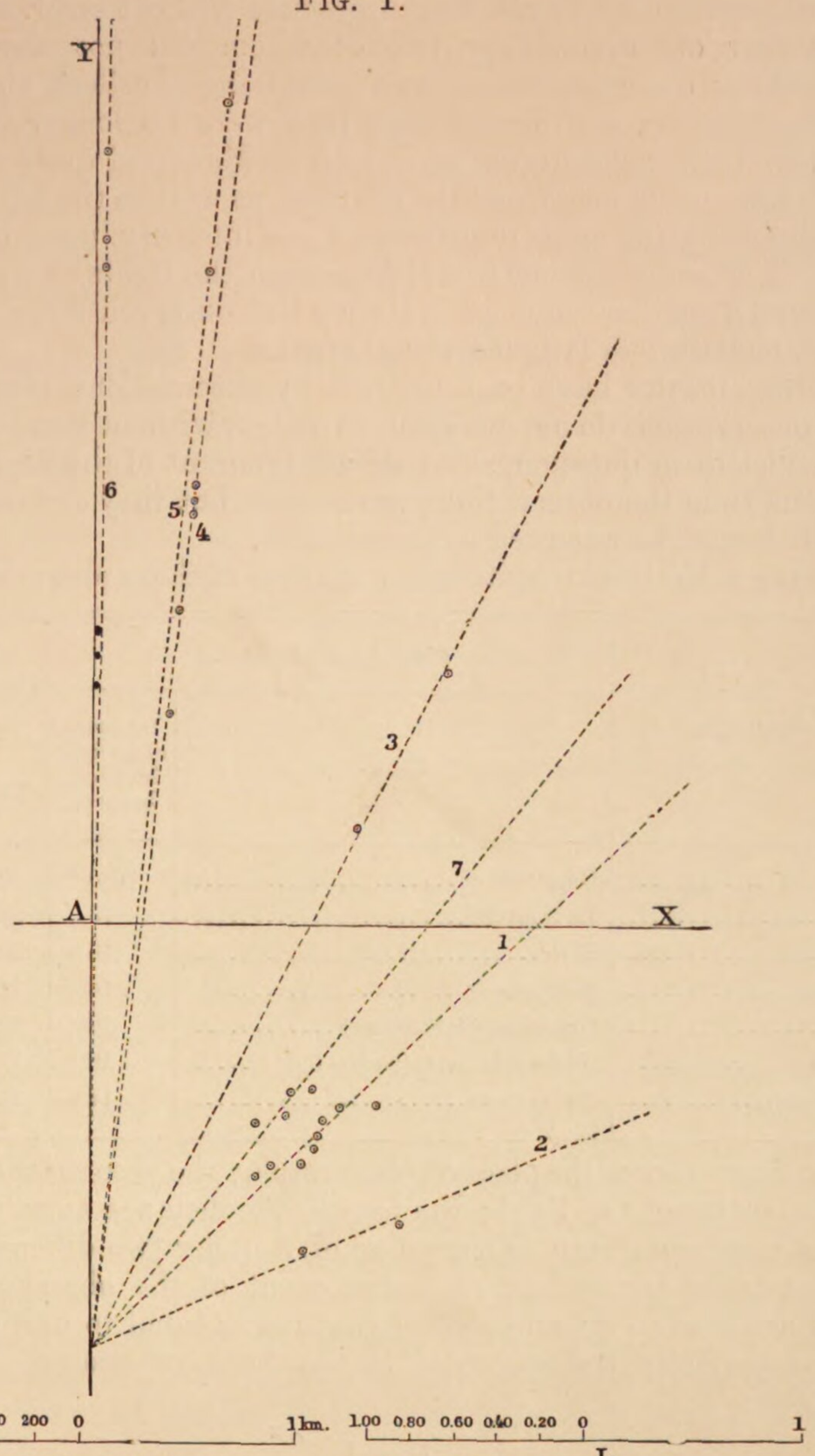
In order to exhibit a recapitulation of the above facts and deduce therefrom practical conclusions, a graphic representation appears to be the most convenient method.

From the equation $$\frac{\mathrm{L}\,a^{x}}{x^{2}} = \lambda$$

we obtain $$\log.\frac{\mathrm{L}}{x^{2}} = x(-\log.a) + \log.\lambda,$$

and, if we represent each observation by a point having for its abscissa the value found for $x$, and for its ordinate the corresponding value of $\log.\frac{\mathrm{L}}{x^{2}}$, all the points belonging to the same experiment, that is to say, the same state of atmosphere, ought to be situated upon a right line, which will have $-\log.a$ for the value of its trigonometrical tangent with the axis of $x$, the ordinate of which at the origin will be equal to $\log.\lambda$. That ordinate should be the same for all the right lines, if the observations were well made, and by persons endowed with the same acuteness of vision.

FIG. 1.




Scale of abscissæ. Scale of ordinates $\log.\frac{\mathrm{L}}{x^{2}}$.

The preceding figure is the graphic representation referred to. It has been drawn on a scale of 0.025 of a meter (one inch nearly) to the unit. The points of construction are inclosed by small circles, and each line is numbered to correspond with the set of experiments of which it expresses the conclusions.

These lines are, without doubt, somewhat arbitrarily traced, the directions given to them being rather forced; the observations tend rather to establish limits than precise values, and it could hardly be otherwise, both on account of the variation of the luminous intensity of the lights and the difficulty of determining the limit of visibility. However, it is seen that the different lines depart but little from the points through which they should have passed in their course if the experiments had been rigorously exact, and that they all unite in the same point on the axis of ordinates. The position of this point gives log. $\lambda = -2.00$, from which we have $\lambda = 0.010$.

The circumstances under which the observations were made would seem to establish the fact that this value of $\lambda$ may be allowed in practice without error. There were always three and sometimes four observers, only two of whom did not wear glasses. A workman employed in making the experiments, and possessing excellent sight, could always see the lights when the observers had agreed that they were no longer visible; finally, gas-lamps were lighted around the inclosure of the Champ de Mars and quite near the lights with which the experiments were being made, and the contrast, as well as the fatigue of the eyes occasioned by constantly observing the lights of greater or less intensity, must have impaired the delicacy of their vision. The same persons would have seen the lights at a greater distance, and have consequently found a smaller value for $\lambda$, if they had observed them in a space not illuminated by street-lamps, or with less fatigued visual organs.

The preceding results have been verified by observations made at several of our light-houses. These observations do not enable us to assign, without some doubt as to its accuracy, a value to the coefficient in question, since we are ignorant of the degree of transparency of the atmosphere at the time the observations were made, but they suffice to establish the fact that this value 0.010 cannot be regarded as a minimum.

The following table is a recapitulation of some of these observations:

| Place of observation. | Light-house observed. | | Distance from place of observation. | | Maximum value of $\lambda$, $a$ being equal to— | |
|---|---|---|---|---|---|---|
| | Name. | Intensity of the light in carcel burners. | Miles. | Kilometers. | 0.973 | 1.00 |
| Mont d'Agde | Cape Bearn | 600 | 50.00 | 92.60 | 0.005548 | 0.069972 |
| Mont d'Agde | La Nouvelle | 16 | 25.75 | 47.69 | 0.001907 | 0.007035 |
| Cape Fréhel | Binic | 16 | 20.50 | 37.97 | 0.003925 | 0.011098 |
| Cape Fréhel | Ile Harbour | 14 | 19.50 | 36.11 | 0.003996 | 0.010737 |
| Cape Fréhel | Granville, (light-house) | 80 | 29.50 | 54.63 | 0.006009 | 0.026805 |
| Baleines, (Ile de Ré) | Sables d'Olonne, (harbor light) | 16 | 17.50 | 32.41 | 0.006273 | 0.015232 |
| Bréhat, (Pointe de Paon) | Ile Harbour | 14 | 13.83 | 25.61 | 0.010589 | 0.021345 |

The first column shows the place of observation; the second, the name of the light-house; the third, the intensity of the light; the fourth, the distance at which it is sometimes seen; the fifth gives a maximum limit to the value of $\lambda$ under two different hypotheses—first, that the coefficient of transparency had, at the moment of the observations, the value of 0.973, which Bouguer assigned to it; and second, that it was equal to unity—that is to say, that the atmosphere was perfectly transparent. It has been calculated, according to the formula above given:

$$\lambda = \mathrm{L}\frac{a^x}{x^2}.$$

It is seen that, if the coefficient of Bouguer be adopted, all these observations, except the last, give values notably less than 0.010, and even if it be supposed that the atmosphere was perfectly transparent one of them brings $\lambda$ down to 0.007 nearly. It is also to be observed that these values are maxima, as the lights were clearly in sight, and some of them remarked to be very brilliant at the time. Thus the observations upon the light of Ile Harbour were made during the months of December, 1860, and January and February, 1861, the light being seen forty-five nights, and appearing very brilliant twenty-one times. On the other hand, the light of La Nouvelle, which gives the lowest value, has been seen but fourteen times in nine years; it is but just to add, however, that the keepers of the light of Agde never observed it but from the interior of their lantern, and did not attach any importance to its discovery. Besides, this value is, under every hypothesis, below that which we have allowed.

Now all these inconveniences will disappear if the degree of transparency of the atmosphere is expressed by the intensity of the unit of light at the unit of distance for an observer with ordinary eyesight, which is represented by the equation $\lambda = 0.010$, with the kilometer for unity. The value of this new coefficient will be deduced from the formula—

$$a^p = 0.010p^2,$$

which gives $p = 10.00$ when $a = 1$, that is to say, when the atmosphere is perfectly transparent, and $p = 8.859$ when $a = 0.973$, the value assigned this coefficient by Bouguer. From the experiment made on the 29th January, we find $p = 0.025$; the 23d of the same month the mean value of $p$ passed from 0.329 to 0.309.

The equation $\mathrm{L}\frac{a^x}{x^2} = \lambda$ shows how the ranges vary with the luminous intensity of the focus and the degree of transparency of the atmosphere, and becomes very striking in a graphic representation. Each of the curves of Plate 2 corresponds to a determined value of $a$ or of $p$. Those of Figure 1 have been traced by projecting the luminous intensities upon the axis of abscissæ to the scale of 0.005 of a meter per 1000 burners, and the ranges upon the axis of the ordinates to the scale of 0 02 of a meter per 100 kilometers. Figure 2 is drawn upon a tenfold larger scale; it is only an enlargement of the square comprised between the dotted lines upon Figure 1, but it gives a larger number of curves.

The upper curve in each figure corresponds to $a = 1$, and is a parabola. The last curve of Figure 2 corresponds to an atmosphere of which the coefficient of transparency would be equal to 0.00000625, that is to say, in which the unit of light would not be seen farther than 50 meters.

An inspection of the figures, and especially of the first, shows how greatly the luminous ranges are reduced by the slightest want of transparency of the atmosphere. When there is sufficient fog to prevent a carcel lamp from being seen at a greater distance than 1000 meters there is no sensible difference in the graphic representation between the range of a light equivalent to 4000 burners and that of a light five times more intense. Calculation gives 2.42 kilometers in the first case, and 2.72 kilometers in the second.

The range of a light of 4000 burners, which would be 632 kilometers in a vacuum, is reduced to 98 kilometers in an atmosphere of which the coefficient of transparency is 0.962, and falls to 16 kilometers when this coefficient becomes 0.632, which is not a rare occurrence, inasmuch as the unit of light can then be seen at 4000 meters distance. It is not more than 1.07 kilometers when the distance at which the unit of light can be seen is reduced to 500 meters. It is also seen that the curves become more nearly parallel to the axis of abscissæ as the value of $a$ diminishes, and from that it may be inferred that *beyond a certain limit there is no great advantage in increasing the intensity of the light.*

These latter considerations are very important, and it may be remarked that they are independent of all hypothesis; an altogether different value for $\lambda$ might be taken, but the conclusion would be the same.

The equation for the ranges is not one of easy application, inasmuch as it requires long calculations for determining $x$, the value of which is usually required; but it may be replaced by graphic illustrations, from which may be obtained the solutions sought with all the accuracy that is practically required; even the curves which the reader has before his eyes give indications which will generally be sufficient.

It is doubtless unnecessary to continue this subject further, and we will now proceed to examine how the points which have just been established enable us to fix the luminous ranges to be given to the apparatus of different orders.

These ranges cannot be determined in an absolute manner; they are necessarily the function of a certain state of the atmosphere. To take the coefficient 0.973 of Bouguer would not answer for the ordinary conditions of the weather; to take a much lower figure would be an unnecessary departure from those conditions, and would give a false idea of the power of our maritime illumination. There would be no advantage in the latter course, as navigators well know that they cannot depend upon the ordinary ranges when the atmosphere is foggy. We have adopted the value 0.903, which corresponds to a range of 7 kilometers, for the unit of light, and which appears to represent an average state of the atmosphere in our climate.

Intensities and luminous ranges.

The following table shows the luminous intensities upon which we can depend in practice, and the corresponding ranges in three states of the atmosphere, which are defined by the expressions $a = 0.966$, $a = 0.903$, and $a = 747$. From observations made at our lighthouses, it seems to be established that along the whole of our Atlantic coast the mean transparency of the atmosphere is greater during one month than is indicated by the first of these values, during six months than is indicated by the second, and during eleven months than is indicated by the last. In the last column of the table are inserted the amplitudes of the flashes of the eclipse lights, and of those which illuminate only a part of the horizon, as the rays emerge from the apparatus. Only white lights are considered, and the proper reduction to be made in the values of the intensities to apply them to colored lights will be found further on.

TABLE OF INTENSITIES AND LUMINOUS RANGES.

| Kind of illuminating apparatus. | Intensity in carcel burners. | | Range in nautical miles, in an atmosphere represented by— | | | | | | Amplitude of the flash, in degrees and tenths of degrees. |
|---|---|---|---|---|---|---|---|---|---|
| | | | $a = 0.966$ $p = 8630m.$ | | $a = 0.903$ $p = 7000m.$ | | $a = 0.747$ $p = 4900m.$ | | |
| | Of fixed light. | Of the flash. | Fixed light. | Flash. | Fixed light. | Flash. | Fixed light. | Flash. | |
| **APPARATUS OF THE 1ST ORDER,** *With lamp consuming 760 gr. colza oil per hour, and giving an intensity of 23 burners.* | | | | | | | | | |
| Fixed light | 630 | ..... | 39.3 | ..... | 20.2 | ..... | 9.8 | ..... | ..... |
| Light with eclipses every minute (Lenses $\frac{1}{8}$; prolonged flashes.) | 60 | 5075 | 21.3 | 59.3 | 12.7 | 27.9 | 6.8 | 12.7 | 9.4 |
| Light with eclipses every 30 seconds (Lenses $\frac{1}{16}$; prolonged flashes.) | 60 | 2525 | 21.3 | 52.2 | 12.7 | 25.2 | 6.8 | 11.7 | 9.4 |
| Light with eclipses every 30 seconds (Lenses $\frac{1}{16}$; short flashes.) | 60 | 3475 | 21.3 | 55.4 | 12.7 | 26.4 | 6.8 | 12.1 | 6.0 |
| Light with eclipses every 20 seconds and less (Lenses $\frac{1}{24}$; short flashes.) | ..... | 2450 | ..... | 51.9 | ..... | 25.1 | ..... | 11.6 | 6.0 |
| Fixed light varied by flashes, (movable lenses of 34° 12′) | 630<br>190 | 4000 | 39.3<br>29.4 | 56.8 | 20.2<br>16.2 | 27.0 | 9.8<br>8.2 | 12.3 | 5.6 |
| **APPARATUS OF THE 2D ORDER,** *With lamp consuming 500 gr. colza oil per hour, and giving an intensity of 15 burners.* | | | | | | | | | |
| Fixed light | 335 | ..... | 33.9 | ..... | 18.0 | ..... | 8.9 | ..... | ..... |
| Light with eclipses every minute (Lenses $\frac{1}{8}$; prolonged flashes.) | 25 | 2550 | 16.2 | 52.3 | 10.3 | 25.3 | 5.8 | 11.7 | 9.4 |
| Light with eclipses every 30 seconds (Lenses $\frac{1}{16}$; prolonged flashes.) | 25 | 1675 | 16.2 | 48.2 | 10.3 | 23.7 | 5.8 | 11.1 | 9.4 |
| Light with eclipses every 30 seconds (Lenses $\frac{1}{16}$; short flashes.) | 25 | 2275 | 16.2 | 51.2 | 10.3 | 24.8 | 5.8 | 11.5 | 6.0 |
| Light with eclipses every 20 seconds and less (Lenses $\frac{1}{20}$; short flashes.) | ..... | 1450 | ..... | 46.9 | ..... | 23.2 | ..... | 10.9 | 6.0 |
| Fixed light varied by flashes, (movable lenses of 43° 40′) | 335<br>95 | 2700 | 33.9<br>24.4 | 52.9 | 18.0<br>14.0 | 25.5 | 8.9<br>7.3 | 11.8 | 5.3 |
| **APPARATUS OF THE 3D ORDER,** (large model,) *With lamp consuming 175 gr. colza oil per hour, and giving an intensity of 5 burners.* | | | | | | | | | |
| Fixed light | 90 | ..... | 24.0 | ..... | 13.9 | ..... | 7.3 | ..... | ..... |
| Light with eclipses every minute (Lenses $\frac{1}{8}$; prolonged flashes.) | 7 | 845 | 10.3 | 41.9 | 7.2 | 21.2 | 4.4 | 10.2 | 8.5 |
| Light with eclipses every 30 seconds (Lenses $\frac{1}{16}$; prolonged flashes.) | 7 | 550 | 10.3 | 38.1 | 7.2 | 19.7 | 4.4 | 9.6 | 8.5 |
| Light with eclipses every 30 seconds (Lenses $\frac{1}{16}$; short flashes.) | 7 | 750 | 10.3 | 40.8 | 7.2 | 20.8 | 4.4 | 10.0 | 5.5 |
| Light with eclipses every 20 seconds and less (Lenses $\frac{1}{16}$; short flashes.) | ..... | 590 | ..... | 38.7 | ..... | 20.0 | ..... | 9.7 | 5.5 |
| Light with flashes every 20 seconds, without eclipses (Lenses $\frac{1}{10}$.) | 50 | 470 | 20.2 | 36.7 | 12.2 | 19.2 | 6.6 | 9.4 | 5.2 |
| Fixed light varied by flashes, (movable lenses of 44° 32′) | 90<br>25 | 950 | 24.0<br>16.2 | 42.9 | 13.9<br>10.3 | 21.6 | 7.3<br>5.8 | 10.3 | 4.7 |
| **APPARATUS OF THE 3D ORDER,** (small model,) *With lamp consuming 110 gr. colza oil per hour, and giving an intensity of 3 burners.* | | | | | | | | | |
| Fixed light | 30 | ..... | 17.2 | ..... | 10.8 | .... | 6.0 | ..... | ..... |
| Light with eclipses every minute (Lenses $\frac{1}{6}$.) | 6 | 275 | 9.7 | 32.4 | 6.9 | 17.4 | 4.2 | 8.7 | 9.0 |

TABLE OF INTENSITIES AND LUMINOUS RANGES—Continued.

| Kind of illuminating apparatus. | Intensity in carcel burners. | | Range in nautical miles, in an atmosphere represented by— | | | | | | Amplitude of the flash, in degrees and tenths of degrees. |
|---|---|---|---|---|---|---|---|---|---|
| | | | $a = 0.966$ $p = 8630m.$ | | $a = 0.903$ $p = 7000m.$ | | $a = 0.747$ $p = 4900m.$ | | |
| | Of fixed light. | Of the flash. | Fixed light. | Flash. | Fixed light. | Flash. | Fixed light. | Flash. | |
| Light with eclipses every 30 seconds and less (Lenses $\frac{1}{10}$.) | 6 | 165 | 9.7 | 28.3 | 6.9 | 15.7 | 4.2 | 8.0 | 9.0 |
| Fixed light varied by flashes, (movable lenses of 50°) | 30<br>8.5 | 238 | 17.2<br>11.1 | 31.2 | 10.8<br>7.7 | 16.9 | 6.0<br>4.6 | 8.5 | 7.0 |
| APPARATUS OF THE 4TH ORDER, 0.375 *of a meter diameter.* | | | | | | | | | |
| Fixed light, with lamp for colza oil, consuming 60 gr. per hour, and giving an intensity of 1.6 burners. | 13 | ..... | 12.9 | ..... | 8.6 | ..... | 5.0 | ..... | ..... |
| Fixed light, with lamp for schist oil, consuming 65 gr. per hour, and giving an intensity of 2.2 burners. | 24 | ..... | 16.0 | ..... | 10.2 | ..... | 5.7 | ..... | ..... |
| Light varied by flashes, with lamp for colza oil, giving an intensity of 1.6 burners, (movable lenses of 61° 34′.) | 13<br>3.7 | 118 | 12.9<br>8.1 | 25.9 | 8.6<br>5.9 | 14.7 | 5.0<br>3.8 | 7.6 | 7.0 |
| Light varied by flashes, with lamp for schist oil, with an intensity of 2.2 burners, (movable lenses of 61° 34′.) | 24<br>6.5 | 221 | 16.0<br>10.0 | 30.6 | 10.2<br>7.1 | 16.7 | 5.7<br>4.3 | 8.4 | 7.0 |
| APPARATUS OF THE 4TH ORDER, 0.30 *of a meter diameter.* | | | | | | | | | |
| Fixed light, with lamp for colza oil, consuming 50 gr. per hour, and giving an intensity of 1.3 burners. | 9 | ..... | 11.3 | ..... | 7.8 | ..... | 4.6 | ..... | ..... |
| Fixed light, with lamp for schist oil, consuming 65 gr. per hour, and giving an intensity of 2.2 burners. | 18 | ..... | 14.5 | ..... | 9.4 | ..... | 5.4 | ..... | ..... |
| Fixed light, in cut glass or in cast glass, for hanging lanterns, with lamp with an intensity of 1.3 burners. | 6 | ..... | 9.7 | ..... | 6.9 | ..... | 4.2 | ..... | ..... |
| APPARATUS FOR LEADING LIGHTS. | | | | | | | | | |
| Lens in cast glass, of 1 meter in diameter, with lamp of an intensity equal to 1.6 burners. | 200 | ..... | 29.8 | ..... | 16.4 | ..... | 8.3 | ..... | 12.0 |
| Lens in cut glass, of 0.50 of a meter in diameter, with lamp of an intensity equal to 1.6 burners. | 300 | ..... | 33.0 | ..... | 17.7 | ..... | 8.8 | ..... | 9.0 |
| Reflector. with an opening of 0.85 of a meter, lamp consum- 175 gr. per hour, and giving an intensity of 5 burners. | 760 | ..... | 40.9 | ..... | 20.8 | ..... | 10.0 | ..... | 18.0 |
| Reflector, with an opening of 0.85 of a meter, lamp consuming 60 gr. per hour, and giving an intensity of 1.6 burners. | 550 | ..... | 38.1 | ..... | 19.7 | ..... | 9.6 | ..... | 12.0 |
| Reflector, with an opening of 0.50 of a meter, lamp consuming 60 gr. per hour, and giving an intensity of 1.6 burners. | 200 | ..... | 29.8 | ..... | 16.4 | ..... | 8.3 | ..... | 20.0 |
| Photophore, with an opening of 0.29 of a meter, lamp consuming 50 gr. per hour, and giving an intensity of 1.3 burners. | 60 | ..... | 21.3 | ..... | 12.7 | ..... | 6.8 | ..... | 36.0 |
| SIDEREAL APPARATUS. | | | | | | | | | |
| Sidereal large burner, with lamp consuming 45 gr. per hour, and giving an intensity of 1.15 burners. | 3.5 | ..... | 7.9 | ..... | 5.8 | ..... | 3.7 | ..... | ..... |

REMARK.—Photometric measurements give much greater intensities than those in the table. Account has been taken of the practical imperfections and of the absorption of the luminous rays by the glass of the lantern. A deduction has also been made for the increased intensity which is obtained by collecting, by means of spherical reflectors, the luminous rays which would diverge uselessly on the land side. The lights varied by flashes present two different periods of light. The most intense continue during the greater part of the time; the other during the eclipses. The ranges assigned to these lights are those of the principal fixed light.

Plate 1 represents in a very satisfactory manner the luminous intensities of our principal illuminating apparatus and the corresponding ranges in the average state of the atmosphere, (that is, when the unit of light has a range of 7 kilometers.) The drawings which form the lower series of figures show the general arrangements of the apparatus and the directions given to the luminous rays. The curves shown in the upper series represent the intensities;

they have, for abscissæ, the durations of the luminous appearances to the scale of 0.03 of a meter per minute, and for ordinates the intensities to the scale of 0.004 of a meter per one hundred burners. The figures relating to the ranges occupy the middle row; they are drawn to the scale of 0.001 per nautical mile, or of 0.00054 of a meter per kilometer. An attempt has been made in these last figures to show the variation of the luminous intensity, which is not the same in the whole illuminated zone.*

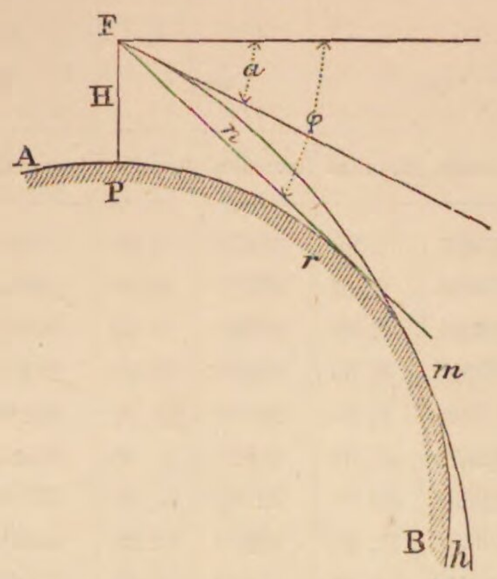
On the inspection of this plate the reader will doubtless be much more impressed than he has been by the preceding calculations, or even by the curves of Plate 2, with *the small increase of range produced by a large increase in intensity of light after we pass a certain limit.*

## GEOGRAPHICAL RANGES.

The distance at which a light may be seen is limited more definitely by the spheroidal form of the earth than by its intensity at the focus. The geographical range depends upon the height of the light above the level of the sea, upon the radius of curvature of that part of the earth's surface at which it is placed and upon the amount of atmospheric refraction.

The luminous rays which traverse the atmosphere pass through strata of air, the density of which diminishes in proportion to its elevation; they undergo successive refractions, and consequently describe curves when their directions are not normal to the surface of the earth. These curves are concave toward the earth, and refraction has the effect of increasing the ranges, as is shown by Figure 2.

FIG. 2.




Let A B be the surface of the sea, F the light, P F its height, F *n m* the curve, which is tangent to the surface of the sea at *m*, F *r* a right line drawn from F and tangent to the surface of the sea at *r*. The geographical range will be equal to P *m*, while it would have only P *r* for its value if there had been no refraction. The luminous ray emitted from the point F is directed tangentially to the surface, and makes, with a horizontal line in the same plane, an angle $a$, which is less than the angle $\varphi$ of the tangent F *r* with the same line.

Atmospheric refraction is not an invariable quantity, but in cases of this kind a mean value may be taken and the ranges deduced from the formula

$$D = \sqrt{\frac{R\ H}{0.42}}$$

in which H is the height of the light above the level of high tide, and R the radius of curvature of the surface. For this last coefficient the value R = 6366953 meters has been adopted, which represents the radius of curvature of the meridian at the latitude of 54° 44′, which may be considered as the mean for the lights on our seacoasts.

*The conception of this last mode of representation belongs to M. Allard, the Engineer-in-chief, and it was carried out under his direction.

The results deduced from this formula give the geographical ranges, supposing that the eye of the observer is placed at the level of the sea. If it were elevated to a height $h$ above that surface, the light could be seen at a distance equal to $\sqrt{\frac{R\ h}{0.42}}$ beyond the point of tangency. The general formula for ranges is, then,

$$P = \sqrt{\frac{R\ H}{0.42}} + \sqrt{\frac{R\ h}{0.42}}.$$

In establishing illuminating apparatus, the angle $a$ which the tangent to the curve at the point F makes with the horizon must also be taken into account, since that determines the direction in which the most intense luminous beam should be directed. This subject will be again referred to when we come to consider the arrangements of the apparatus.

The following table shows, in kilometers and nautical miles, the geographical ranges corresponding to different heights above the level of the sea, both of the focus of the apparatus and the eye of the observer:

TABLE OF GEOGRAPHICAL RANGES.

| Height of luminous focus above the level of the sea. | Distance of the point of contact of the luminous ray tangent to the surface of the sea, $D=\sqrt{\frac{R\ H}{0.42}}$ R = 6366953. | | Geographical Ranges. For an observer of whose height $h$, above the level of the sea, is equal to— | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3m. | | 6m. | | 9m. | | 12m. | | 15m. | | 20m. | |
| | In meters. | In miles. | In meters. | In miles. | In meters. | In miles. | In meters. | In miles. | In meters. | In miles. | In meters. | In miles. | In meters. | In miles. |
| 1 | 3894 | 2.10 | 10638 | 5.74 | 13431 | 7.25 | 15575 | 8.41 | 17382 | 9.39 | 18973 | 10.25 | 21306 | 11.51 |
| 2 | 5506 | 2.97 | 12250 | 6.62 | 15043 | 8.12 | 17187 | 9.28 | 18994 | 10.26 | 20585 | 11.12 | 22918 | 12.38 |
| 3 | 6744 | 3.64 | 13488 | 7.28 | 16281 | 8.79 | 18425 | 9.95 | 20232 | 10.93 | 21823 | 11.78 | 24156 | 13.04 |
| 4 | 7787 | 4.20 | 14531 | 7.85 | 17324 | 9.35 | 19468 | 10.51 | 21275 | 11.49 | 22866 | 12.35 | 25199 | 13.61 |
| 5 | 8706 | 4.70 | 15450 | 8.34 | 18243 | 9.85 | 20387 | 11.01 | 22194 | 11.98 | 23785 | 12.84 | 26118 | 14.10 |
| 6 | 9537 | 5.15 | 16281 | 8.79 | 19074 | 10.30 | 21218 | 11.46 | 23025 | 12.43 | 24616 | 13.29 | 26949 | 14.55 |
| 7 | 10301 | 5.56 | 17045 | 9.20 | 19838 | 10.71 | 21982 | 11.87 | 23789 | 12.85 | 25380 | 13.71 | 27713 | 14.97 |
| 8 | 11013 | 5.95 | 17757 | 9.59 | 20550 | 11.10 | 22694 | 12.25 | 24501 | 13.23 | 26092 | 14.09 | 28425 | 15.35 |
| 9 | 11681 | 6.31 | 18425 | 9.95 | 21218 | 11.46 | 23362 | 12.62 | 25169 | 13.59 | 26760 | 14.45 | 29093 | 15.71 |
| 10 | 12312 | 6.65 | 19056 | 10.29 | 21849 | 11.80 | 23993 | 12.96 | 25800 | 13.93 | 27391 | 14.79 | 29724 | 16.05 |
| 11 | 12913 | 6.97 | 19657 | 10.61 | 22450 | 12.12 | 24594 | 13.28 | 26401 | 14.26 | 27992 | 15.12 | 30325 | 16.38 |
| 12 | 13488 | 7.28 | 20232 | 10.93 | 23025 | 12.43 | 25169 | 13.59 | 26976 | 14.57 | 28567 | 15.43 | 30900 | 16.69 |
| 13 | 14038 | 7.58 | 20782 | 11.22 | 23575 | 12.73 | 25719 | 13.89 | 27526 | 14.86 | 29117 | 15.72 | 31450 | 16.98 |
| 14 | 14568 | 7.87 | 21312 | 11.51 | 24105 | 13.02 | 26249 | 14.17 | 28056 | 15.15 | 29647 | 16.01 | 31980 | 17.27 |
| 15 | 15079 | 8.14 | 21823 | 11.78 | 24616 | 13.29 | 26760 | 14.45 | 28567 | 15.43 | 30158 | 16.29 | 32491 | 17.55 |
| 20 | 17412 | 9.40 | 24156 | 13.04 | 26949 | 14.55 | 29093 | 15.71 | 30900 | 16.69 | 32491 | 17.55 | 34824 | 18.80 |
| 25 | 19468 | 10.51 | 26212 | 14.15 | 29005 | 15.66 | 31149 | 16.82 | 32956 | 17.80 | 34547 | 18.65 | 36880 | 19.92 |
| 30 | 21326 | 11.52 | 28070 | 15.16 | 30863 | 16.67 | 33007 | 17.82 | 34814 | 18.80 | 36405 | 19.66 | 38738 | 20.92 |
| 35 | 23034 | 12.44 | 29778 | 16.08 | 32571 | 17.59 | 34715 | 18.75 | 36522 | 19.72 | 38113 | 20.58 | 40446 | 21.84 |
| 40 | 24625 | 13.30 | 31369 | 16.94 | 34162 | 18.45 | 36306 | 19.61 | 38113 | 20.58 | 39704 | 21.44 | 42037 | 22.70 |
| 45 | 26118 | 14.10 | 32862 | 17.75 | 35655 | 19.25 | 37799 | 20.41 | 39606 | 21.39 | 41197 | 22.25 | 43530 | 23.51 |
| 50 | 27531 | 14.87 | 34275 | 18.51 | 37068 | 20.02 | 39212 | 21.17 | 41019 | 22.15 | 42610 | 23.01 | 44943 | 24.27 |
| 55 | 28875 | 15.59 | 35619 | 19.23 | 38412 | 20.74 | 40556 | 21.90 | 42363 | 22.88 | 43954 | 23.74 | 46287 | 24.99 |
| 60 | 30159 | 16.29 | 36903 | 19.93 | 39696 | 21.44 | 41840 | 22.59 | 43647 | 23.59 | 45238 | 24.43 | 47571 | 25.69 |
| 65 | 31390 | 16.95 | 38134 | 20.59 | 40927 | 22.10 | 43071 | 23.26 | 44878 | 24.23 | 46469 | 25.09 | 48802 | 26.35 |
| 70 | 32575 | 17.59 | 39319 | 21.23 | 42112 | 22.74 | 44256 | 23.90 | 46063 | 24.87 | 47654 | 25.73 | 49987 | 26.99 |

TABLE OF GEOGRAPHICAL RANGES—Continued.

| Height of luminous focus above the level of the sea. | Distance of the point of contact of the luminous ray tangent to the surface of the sea, $D=\sqrt{\frac{R\ H}{0.42}}$ R=6366953. | | Geographical Ranges. For an observer of whose height *h*, above the level of the sea, is equal to— | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3*m*. | | 6*m*. | | 9*m*. | | 12*m*. | | 15*m*. | | 20*m*. | |
| | In meters. | In miles. | In meters. | In miles. | In meters. | In miles. | In meters. | In miles. | In meters. | In miles. | In meters. | In miles. | In meters | In miles. |
| 75 | 33719 | 18.21 | 40463 | 21.85 | 43256 | 23.36 | 45400 | 24.52 | 47207 | 25.49 | 48798 | 26.35 | 51131 | 27.61 |
| 80 | 34825 | 18.81 | 41579 | 22.45 | 44362 | 23.96 | 46506 | 25.11 | 48313 | 26.09 | 49904 | 26.95 | 52237 | 28.21 |
| 85 | 35896 | 19.38 | 42640 | 23.03 | 45433 | 24.53 | 47577 | 25.69 | 49384 | 26.67 | 50975 | 27.53 | 53308 | 28.79 |
| 90 | 36937 | 19.95 | 43681 | 23.59 | 46474 | 25.10 | 48618 | 26.25 | 50425 | 27.23 | 52016 | 28.09 | 54349 | 29.35 |
| 95 | 37949 | 20.49 | 44693 | 24.13 | 47486 | 25.64 | 49630 | 26.80 | 51437 | 27.78 | 53028 | 28.64 | 55361 | 29.89 |
| 100 | 38935 | 21.02 | 45679 | 24.67 | 48472 | 26.17 | 50616 | 27.33 | 52423 | 28.31 | 54014 | 29.17 | 56347 | 30.43 |
| 110 | 40835 | 22.05 | 47579 | 25.69 | 50372 | 27.20 | 52516 | 28.36 | 54323 | 29.33 | 55914 | 30.19 | 58247 | 31.45 |
| 120 | 42651 | 23.03 | 49395 | 26.67 | 52188 | 28.18 | 54332 | 29.34 | 56139 | 30.32 | 57730 | 31.17 | 60063 | 32.43 |
| 130 | 44393 | 23.97 | 51137 | 27.61 | 53930 | 29.12 | 56074 | 30.28 | 57881 | 31.26 | 59472 | 32.11 | 61805 | 33.37 |
| 140 | 46069 | 24.88 | 52813 | 28.52 | 55606 | 30.03 | 57750 | 31.19 | 59557 | 32.16 | 61148 | 33.02 | 63481 | 34.28 |
| 150 | 47686 | 25.75 | 54430 | 29.39 | 57223 | 30.90 | 59367 | 32.06 | 61174 | 33.03 | 62765 | 33.89 | 65098 | 35.15 |
| 160 | 49249 | 26.59 | 55993 | 30.24 | 58786 | 31.74 | 59930 | 32.90 | 62737 | 33.88 | 64328 | 34.74 | 66661 | 36.00 |
| 170 | 50765 | 27.41 | 57509 | 31.05 | 60302 | 32.56 | 62446 | 33.72 | 64253 | 34.70 | 65844 | 35.56 | 68177 | 36.82 |
| 180 | 52237 | 28.21 | 58981 | 31.85 | 61774 | 33.36 | 63918 | 34.52 | 65725 | 35.49 | 67316 | 36.35 | 69649 | 37.61 |
| 190 | 53668 | 28.98 | 60412 | 32.62 | 63205 | 34.13 | 65349 | 35.29 | 67156 | 36.26 | 68747 | 37.12 | 71080 | 38.38 |
| 200 | 55063 | 29.73 | 61807 | 33.38 | 64600 | 34.88 | 66744 | 36.04 | 68551 | 37.02 | 70142 | 37.88 | 72475 | 39.14 |
| 220 | 57750 | 31.19 | 64494 | 34.83 | 67287 | 36.33 | 69431 | 37.49 | 71238 | 38.47 | 72829 | 39.33 | 75162 | 40.59 |
| 240 | 60318 | 32.57 | 67062 | 36.21 | 69855 | 37.72 | 71999 | 38.88 | 73806 | 39.86 | 75397 | 40.71 | 77730 | 41.97 |
| 260 | 62781 | 33.90 | 69525 | 37.54 | 72318 | 39.05 | 74462 | 40.21 | 76269 | 41.19 | 77860 | 42.04 | 80193 | 43.30 |
| 280 | 65151 | 35.18 | 71895 | 38.82 | 74688 | 40.33 | 76832 | 41.49 | 78639 | 42.47 | 80230 | 43.32 | 82563 | 44.58 |
| 300 | 67438 | 36.42 | 74182 | 40.06 | 76975 | 41.57 | 79119 | 42.72 | 80926 | 43.70 | 82517 | 44.56 | 84850 | 45.82 |

All of our lights are not placed at a sufficiently great elevation to enable them to be seen by an observer from the deck of a vessel at the limit of their ranges, and the values in this table, or, in their default, the formula from which they were derived, enable us to ascertain the point at which it is necessary to be elevated above the level of the sea in order to perceive in the horizon a light the position and elevation of which are known. Navigators may thus judge approximately of their distance from a light by observing the moment it appears to come up out of the sea The heights of the light-houses being given in the nautical documents with reference to the level of the highest water, it will be necessary, in order to be more accurate, to add to the height of the light-houses the difference between that level and that of the sea at the moment the observation is made.

Thus let us suppose it were necessary to have an elevation of 12 meters above the level of the sea to note the first appearance of a light whose height is 42 meters, and that at the moment of observation the level of the water is 3 meters below that of the highest tides, it will be found from the table that the distance to the foot of the tower is 21.39 miles

This is, to be sure, not rigorously exact, but it will be readily seen that approximate results are quite admissible in such a matter.

## IV. RELATIVE POSITIONS OF ASSOCIATED LIGHTS.

The use of two or more lights at a single station has two distinct objects, viz: to give the station a decided characteristic and to mark a certain direction. In the first case the distance between the lights should be such that they shall always appear distinct, and not blend within the limits of their range; in the second they must be so arranged that they will not only appear distinct, but the navigator when he sees them will recognize any departure from the prolongation of the straight line which joins them—that is to say, so as to enable him to perceive that they are no longer in the same vertical plane, before he runs on those dangers, clear of which they are intended to guide.

The elements of the question are confined to the phenomena of irradiation when it is simply proposed to obtain a distinctive characteristic: but when it is proposed to establish range or leading lights, it will be necessary, besides, to take into account the accuracy of judgment of the observer, or, in other words, the value of the angle which is made by the projection on a horizontal plane of the two lines joining the luminous points and the observer's eye, so that men who are little accustomed to forming estimates of this kind may readily see that these luminous points are not situated in the same vertical plane. The two problems, then, should be considered separately.

Irradiation.

It is known that the amplitude of irradiation depends upon three things—the luminous intensity of the object, the darkness of the background upon which it is projected, and the degree of short-sightedness of the observer. It increases with each of them. In order to illustrate this last point more clearly, we will cite the following experiments made upon the gas-lamps of the city of Paris by four persons of different powers of vision. These lights, placed on two sides of a bridge, were observed from one of the adjacent quays which extended in a straight line from it. The observers withdrew farther and farther from the bridge until the luminous halos, which, to their eyes, encircled two lamps opposite to each other, appeared to them tangent, yet leaving the lights perfectly distinct to their vision.

Effects of short-sightedness.

Three of these observers were short-sighted, and the numbers of the glasses suited to them were No. 8 for the first, No 11 for the second, and No. 16 for the third. They did not on this occasion use glasses The fourth had excellent sight. The distances at which the lights were observed varied from 95 to 626 meters; the night was dark, the atmosphere very clear, and distance does not seem (between these limits) to have had any appreciable influence upon the phenomenon. Each person made several observations, agreeing within a few minutes. The mean results of the observations gave the following for the amplitude of the apparent irradiations:

| | | | |
|---|---|---|---|
| 1st observer | 1° | 12′ | 15″ |
| 2d observer | 1° | 7′ | 22″ |
| 3d observer | | 57′ | 7″ |
| 4th observer | | 12′ | 0″ |

It is thus seen how important it is that near-sighted persons should not be employed as pilots.*

The more important experiments which follow were made by persons who had good sight or wore spectacles to assure it. Two men who possessed remarkably acute vision took part in the work, but did not think proper to submit their observations, because they were considered as having exceptionally good eyes. They served, however, to establish the fact that the other observers were within the ordinary conditions found in practice.

Angles at which the lights blend.

The first trial was to determine the smallest angle under which two lights can be seen and yet appear perfectly distinct.

Trial was made in succession with carcel lamps, lenticular apparatus of 0.30 of a meter diameter, parabolic reflectors of 0.29 of a meter opening, lenses of fixed-light apparatus of the first order, and large annular lenses of the same class. The observers (three in number)

*It is to be remarked that spectacles, which remedy that infirmity under ordinary circumstances, are but a poor palliative at sea, where the glasses soon become covered with moisture, or with crystals of salt, and thus lose much of their transparency.

placed themselves at different distances from the lights, and indicated, by means of signals previously agreed upon, the direction in which the illuminating apparatus, placed upon a horizontal track, should be moved. They agreed remarkably in their observations. The night was dark and the atmosphere clear. The following table will show the results obtained:

| Apparatus. | Luminous intensity. | | Separation of the lights. | Distance of observers. | Visual angle. | Appearance of the lights. |
|---|---|---|---|---|---|---|
| | Total. | Per square centimeter. | | | | |
| | *Burners.* | *Burners.* | *m.* | *m.* | ′ ″ | |
| Carcel lamps | 1.0 | 0.11 | 0.90 | 965 | 3 12 | Almost blended. |
| | | | 0.90 | 1004 | 3 5 | Blended. |
| | | | 0.90 | 500 | 6 11 | Sufficiently distinct. |
| | | | 1.00 | 1004 | 3 25 | Almost blended. |
| | | | 1.00 | 1300 | 2 39 | Blended. |
| | | | 1.00 | 610 | 5 38 | Sufficiently distinct. |
| | | | 1.10 | 725 | 5 13 | The same. |
| | | | 1.20 | 810 | 5 6 | The same. |
| | | | 1.30 | 850 | 5 15 | The same. |
| | | | 1.40 | 965 | 4 59 | The same. |
| Catadioptric apparatus of 0.30*m* | 10 | 0.125 | 1.00 | 772 | 4 27 | Almost blended. |
| | | | 1.00 | 600 | 5 44 | Not sufficiently distinct. |
| | | | 1.20 | 1407 | 2 56 | Blended. |
| | | | 1.20 | 600 | 6 52 | Sufficiently distinct. |
| | | | 1.50 | 772 | 6 41 | The same. |
| Parabolic reflectors, white | 80 | 0.13 | 1.00 | 1030 | 3 20 | Blended. |
| | | | 1.40 | 675 | 7 8 | Not sufficiently distinct. |
| | | | 1.50 | 675 | 7 38 | Sufficiently distinct. |
| Parabolic reflectors, with lights colored red by means of a pane of glass | ..... | ..... | 1.50 | 850 | 6 4 | The same. |
| Parabolic reflectors, one white and one red | ..... | ..... | 1.40 | 772 | 6 14 | The same. |
| | | | 1.30 | 772 | 5 47 | Not sufficiently distinct. |
| | | | 1.10 | 590 | 6 25 | Sufficiently distinct. |
| | | | 1.00 | 500 | 6 52 | The same. |
| | | | 0.90 | 500 | 6 11 | Not sufficiently distinct. |
| Lamps of 1st order, with dioptric lenses of a fixed light, one meter in height | 400 | 0.44 | 2.90 | 673 | 14 49 | Sufficiently distinct. |
| | | | 4.40 | 1154 | 13 6 | Not quite distinct enough. |
| | | | 3.70 | 1154 | 11 1 | Not sufficiently distinct. |
| Lamps of 1st order, with annular lenses of one meter in height, embracing $\frac{1}{3}$ of the circumference | 3,000 | 0.43 | 2.00 | 800 | 8 36 | Almost blended. |
| | | | 3.00 | 800 | 12 53 | Not quite distinct enough. |
| | | | 3.00 | 700 | 14 44 | Very distinct. |
| | | | 3.24 | 772 | 14 26 | Sufficiently distinct. |
| | | | 3.74 | 890 | 14 27 | The same. |
| | | | 4.14 | 1004 | 14 11 | The same. |
| | | | 4.50 | 1100 | 14 4 | The same. |
| | | | 3.00 | 1407 | 7 20 | Complete confusion. |
| | | | 5.00 | 1407 | 12 13 | Not sufficiently distinct. |
| | | | 6.00 | 1407 | 14 40 | Sufficiently distinct. |
| | | | 6.00 | 2750 | 7 30 | Complete confusion. |
| | | | 9.00 | 2750 | 11 15 | Not sufficiently distinct. |
| | | | 11.00 | 2750 | 13 45 | Almost sufficiently distinct. |
| Lamps of 1st order, with annular lenses of one meter in height, embracing $\frac{1}{16}$ of the circumference | 1,500 | 0.43 | 2.00 | 1100 | 6 15 | Complete confusion. |
| | | | 4.50 | 1100 | 14 4 | Sufficiently distinct. |

It is seen that, excepting some slight anomalies inherent in experiments of this sort, the irradiation augments not with the power of the focus, but with the luminous intensity per unit of surface of the illuminating body.

If the luminous intensities decreased in proportion to the square of the distance, the amplitude of the irradiation would be the same whatever might be the distance of the observer; but this is not the case; the decrease is more rapid, and the radiation diminishes with the distance in a proportion much greater as the atmosphere diminishes in clearness, except, however, during rain and thick fog, as has been established by observations which will presently be referred to. It follows that the figures deduced from experiments which have not been carried beyond a distance of 2750 meters may be considered as *maxima*, with the advantage of errors in our favor; this might be considered a fair allowance. Nevertheless the Lighting Service thought it would be well to go farther, and not wishing to enter into details which could not be easily reconciled with the exigencies of practice, and which would be of too absolute a character, it has fixed the following as the least angle which two lights ought to make in order to appear sufficiently distinct:

| | |
|---|---|
| * For small lights (fanaux) - - - - - - - - - | 8′ |
| For lights of the three larger orders - - - - - - - | 15′ |

Influence of the state of the atmosphere.

Observations made at sea upon multiple lights, and under different circumstances, establish the fact that these figures can be relied upon. They have shown, besides, that fog and rain exert upon the phenomena under discussion an influence which may be easily conceived, but which cannot well be verified. Although the lights lose part of their brilliancy in these states of the atmosphere, yet irradiation appears to increase in a certain proportion. This may be attributed to the fact that those drops of rain or vescicles of fog nearest to the light are illuminated with sufficient vividness to send luminous rays to the observer, and increase in that way the dimensions of the illuminating body. This irradiation, however, does not exceed the limits which have just been given

Thus, the two tide-lights at the port of Boulogne, one of which is elevated three meters above the other, have been distinguished at a distance of two miles in clear weather, and were blended at less than one and a half miles during a fog. The visual angle, in the first case, was 2′ 47″, and in the second, 3′ 43″. These observations were made by a pilot who had good sight, as is proved by the small value of the angles under which the vision was distinct.

Thus, again, two fixed lights of the first order, at the mouth of the Canche, are seen from the light at Alpreck, under an angle of 4′ 10″, at a distance of eleven and a half miles, and they appear distinct or blended, according to the state of the atmosphere. In 10.9 observations made during the course of a year the lights were visible 206 times during fog, and appeared distinct only 94 times, being 46 per cent.; during rain they were seen 63 times, but appeared distinct only 14 times, being 22 per cent.; during clear weather, or with clouded sky without rain or apparent fog, they were seen 533 times, and remained distinct 409 times, being 77 per cent.

## MULTIPLE LIGHTS.

The angles 8′ for small lights and 15′ for those of the higher orders being admitted, the solution of the problem of the establishment of multiple lights as a distinctive characteristic is very easy, especially when we make use of the simplifications which are allowable in practice.

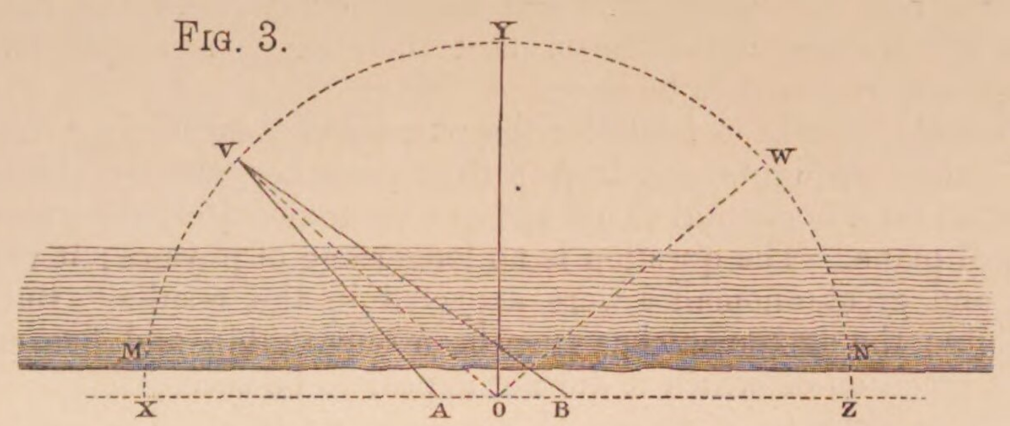
Let M N (Fig 3) be the portion of the shore-line which it is proposed to light, O a point on the line joining the two lights and midway between them, the circular arc X Y Z the limit of the range of these lights. (This arc is described from the point O, and may be substituted without sensible error for the nearly identical arcs described from each light as a

* In the French service all lights of the first three orders are called *phares*, all below those orders *fanaux*.

center,) V O W the angle embracing all the directions in which it is important that a navigator should recognize the character of the illumination at the point O—that is to say, where he may find himself in view of these lights before having seen any other. The line joining the lights ought to be perpendicular to the line bisecting the angle V O W; and, if we call $x$ the distance A B between the two lights, $p$ the line O V or the range, $a$ the angle V O Y $= \frac{\text{V O W}}{2}$,

we will then have $x = 2\,p\,\frac{\sin 4'}{\cos a}$ for lights of the lower orders, and $x = 2\,p\,\frac{\sin 7'\,30''}{\cos a}$ for those of the larger orders.

FIG. 3.




When there is no objection, we usually give to $x$ a higher value than these equations indicate. Thus, for the lights of the first order at the mouth of the Canche, $p = 37000$ meters, and $a$ not greater than 45°, we find, according to the formula, $x = 228.31$ meters, and the distance between the lights has been fixed at 250 meters.

The arrangement of which we have just spoken, implies that lights can only preserve their distinctive character in an angular space considerably less than 180°. Such is the case with all of this description which have been established on the coasts of France. It allows the same elevation to be given to each of the lights belonging to the same group, and it is easy to see that there is a double advantage in this. There is economy in the expense of construction, for the two heights are jointly regulated to suit the required range; and (as) two lights of different elevations are liable to be differently affected by fog, the navigator might think that one of them was much farther off than the other, and thus be deceived in regard to the character of the illumination.

But if both lights ought to be seen through an arc of the horizon of 180° or more, it would be necessary to construct the light-houses of different elevations, and to place them so that the lower one may never be obscured by the upper. The line which joins them, produced, ought to divide the space to be illuminated into about equal parts, and the difference in height should be determined theoretically, according to the condition that the two lights should not be seen from any points where they should appear distinct, under a less angle than 8′ if they are of the lower, and 15′ if they are of the higher orders. But it is easy to see that, on account of their great range, it is almost impossible to satisfy this last condition in the case of apparatus of the two larger orders. Even if we admit that the light would appear sufficiently distinct under an angle of 12′, a difference of 100 meters in their heights would not prevent confusion beyond a distance of about 15 miles.

The problem is hardly ever susceptible of a practical solution when the angle $a$ approaches 90° or goes beyond that limit; the lights then blend into one through a more or less extended part of the maritime horizon.

## LEADING LIGHTS.

There are many leading lights on our channel and Atlantic coasts, where there are numerous narrow passages. There are but few on our Mediterranean coast.

The power of these lights varies according to local circumstances. The light at Fatouville, which has already been referred to, is of the first order, and is associated with a light of the third order upon the pier of the hospital at Honfleur, to guide clear of the Ratier shoal, which is nearly ten miles distant. The entrance to the harbor of Brest is marked by the lights of Portzic and of Petit-Minou, one of the second and the other of the third order. The direction of the main channel of the mouth of the Loire is marked by two lights of the third order, the Commerce and the Aiguillon. But almost everywhere the lights of the fourth order are used for this service for the reason that their range is ample for the distance at which they are actually required to be seen.

Many experiments have been made for the purpose of determining the minimum angle which the lines joining two lights, one higher than the other, and an observer's eye, should make when projected on a horizontal plane and yet be immediately recognized as not situated in the same vertical plane. The question is no longer one of physics: it rests upon elements of another order, and great anomalies were expected in the results. But they have been generally very slight; the agreement has even been remarkable, and has enabled us to treat the subject with a precision of which it did not appear to be susceptible.

We will limit ourselves to citing one of these experiments. The lights were from small apparatus of cast glass, the intensities of which were estimated to be equal to six carcel burners. The vertical distance which separated them could be varied, and the lower light was movable on a horizontal track, perpendicular to the line joining the upper light with the place from which the observations were made. This station was 772 meters distant from the lights. The observers were three in number, and after having placed the lower light on the same vertical line with the other, it was moved, 10 centimeters at a time, until it was so clearly shown to be out of that line that there could be no possible mistake, even among persons unaccustomed to such observations. The following table shows the facts observed:

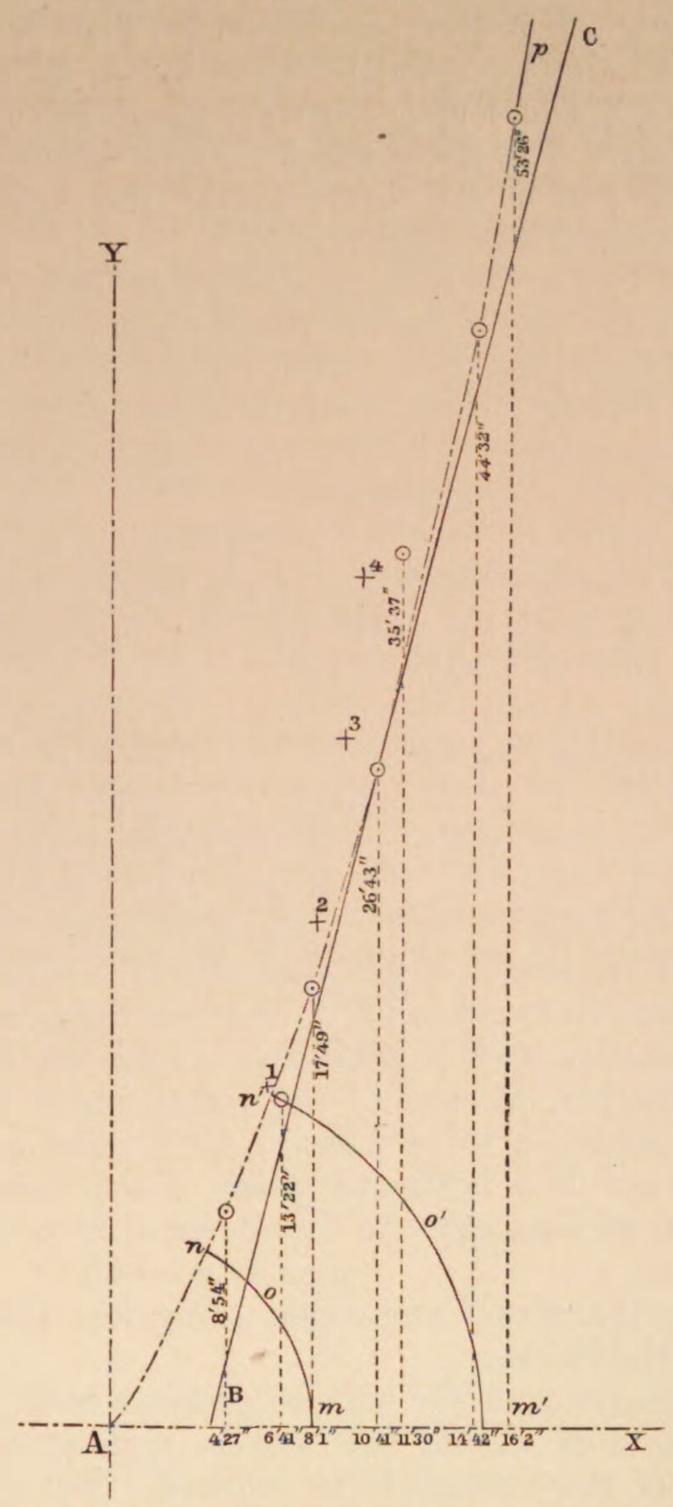
| VERTICAL DISTANCE. | | HORIZONTAL SEPARATION. | | Angle which the line joining the lights makes with the vertical. |
|---|---|---|---|---|
| Linear. | Angular. | Linear. | Angular. | |
| *m.* | ′ ″ | *m.* | ′ ″ | ° ′ |
| 2.00 | 8 54 | 1.00 | 4 27 | 26 34 |
| 3 00 | 13 22 | 1.50 | 6 41 | 26 34 |
| 4.00 | 17 49 | 1.80 | 8 1 | 24 14 |
| 6.00 | 26 43 | 2.40 | 10 41 | 21 48 |
| 8.00 | 35 37 | 2.60 | 11 35 | 18 0 |
| 10.00 | 44 32 | 3.30 | 14 42 | 18 16 |
| 12.00 | 53 26 | 3.60 | 16 2 | 16 42 |

It is seen that the horizontol separation increases as the vertical distance between them increases, but that, nevertheless, the angle formed with the vertical by the line joining the two lights diminishes at the same time.

The results of the observations may be represented by a graphic construction, which will show their agreement with sufficient clearness except in two points, those which correspond to the vertical angular distances 13′ 22″ and 35′ 37″, which evidently indicate errors of observation.

In taking for ordinates the vertical, and for abscissæ the horizontal angular distances, we obtain a series of points belonging to a regular curve, leaving out of account the two anomalies of which we have just spoken, which, however, are not very marked.

FIG. 4.




The lower light being placed at A. the origin of coördinates, the successive positions of the upper light may be represented in the limits of the observation by an arc of a parabola of the third degree, A $n\ p$, which will have for equation:

$$y = 1.88\ x + 0.0054\ x^3.$$

But it is to be remarked that two lights would blend near the origin, and that this curve ought not to be accepted, except at a distance of 8′ from the point A, if the lights be of little intensity, and of 15′ if of the three larger orders; these angles being regarded as the smallest under which the lights are well defined, as has been previously stated. The geometrical location of the positions of the upper light is then determined by the arc of the parabola $n\ p$ and by the arc of the circle $n\ o\ m$ in the first case, and by the curve $n'\ p$ and the arc $n'\ o'\ m'$ in the second.

The calculation of the value of $x$ is unnecessarily long for practical purposes; it was accordingly thought best to substitute for the parabola a right line, which approaches very nearly the middle part, and has for equation

$$y = 4\ (x - 4'.)$$

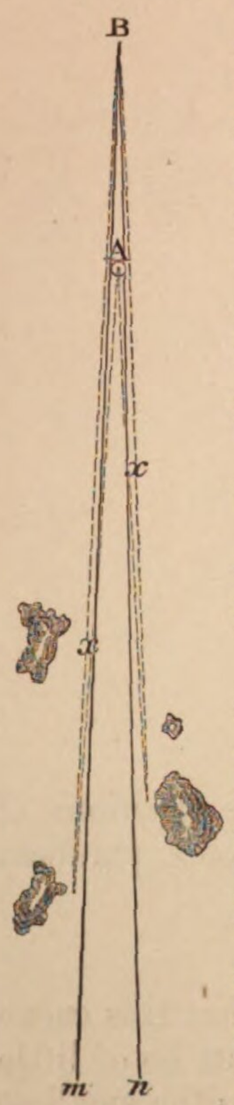
This line passes through one of the points of observation, and leaves all the others nearer to the vertical. The solutions which it gives are, therefore, more favorable to the mariner than those of the parabola. It is indicated upon the figure by the letters B C.

The points marked 1, 2, 3, and 4 upon the same figure belong to a series of observations made with parabolic reflectors. The curve which may be deduced from them indicates more accuracy of judgment on the part of the observer than the preceding one; the latter exacts the most angular space between the two lights.

The relative heights of two lights forming a range or lead, should be such that the one farthest off can never be masked to the eyes of the navigator by the structure which supports the other. But it is not always possible to fulfill this condition; it is then necessary that the limits of occultation should be sufficiently within those of the channel, that one may be assured of being in good water when only one light is seen, and that there may be time to return to it when the second becomes unmasked.

If the passage be very narrow, a moment of inattention, an accidental occultation of the more distant light, or its momentary extinction, might lead to serious consequences. In such cases it would be better not to mark the passage if it be impossible to place the lights in such a position that they might both be always in sight.

FIG. 5.




In studying the relative positions to be given to two lights that are required to mark a range, we proceed as follows: The site A of the lower light is usually determined by local circumstances; the higher one is then assigned a position which at first appears best to fulfill the requirements of the case. Examination is then made to ascertain if this last light can, without entailing too great expense, be established at such an elevation above the other, that it may be seen through the entire length of the channel; if this cannot be arranged, and if no other point can be found to fulfill that condition, care is then taken that the angle of occultation $m$ B $n$ shall not exceed the desired limits; finally, it is ascertained whether, at each of the points where the mariner must keep well away from a danger, a value is found for $x$ (that is to say, for the angle made by the projection on a horizontal plane of the lines joining the observer's eye and the lights) at least equal to that deduced from the formula

$$y = 4\ (x - 4')$$

without the actual visual angle ever being less than 8′ or 15′, according to the intensities of the lights.

The same characteristic may be given to each light when their heights are such that the most distant one will be seen above the other throughout the entire length of the channel to be marked. But when that is not the case it will be proper to have their characteristics different, as has been observed, so that the navigator may see at once in what direction he should steer to place himself upon the true course. A fixed light may be associated with a fixed light varied by flashes, or a white light with a red one, and the upper or higher light should have more power in proportion as the distance which separates them is greater. Lights with long eclipses are not employed, for the reason that both lights should always be in sight from the channel, or if one of them disappear at all, it should be at rare and short intervals.

The leading lights that guide through the channel of the Sables d'Olonne, for example, are both fixed white, because La Chaume light is seen above the other throughout the whole length of the channel. The lights of St. George and of the dunes of Suzac which mark the entrance to the Gironde, are in similar positions and are both fixed, but they have been colored red to distinguish them from the numerous lights on the adjacent coast. The entrance to the channel of Brest is marked by the fixed white light of Petit-Minou, (third order,) and by the light varied by flashes on the point of Portzic, (second order;) this difference in their characteristics and orders was deemed necessary, for the reason that the latter appears below

the other when the observer is but a short distance off, and is separated from it by a distance of 6400 meters.

It frequently happens that one of the lights need illuminate but a very small arc. The mariner then sees but a single light in the greater portion of the maritime horizon, but he recognizes it before entering the channel, and always knows the course which he should steer to enable him to see the second before encountering dangers. This circumstance is made use of to diversify the characteristics or the ranges without an increase of expense. When the distance at which the lights should be seen does not exceed a few miles, a small catadioptric apparatus of the fourth order is used for the one which is to illuminate the entire horizon, and a parabolic reflector of 0.29 of a meter opening for the one required to light the small arc. If either be colored it should be the latter, because more intense than the former; without requiring to be of greater range, it may be deprived without detriment of part of its brilliancy. The intensity of the first varies from nine to eighteen burners, and that of the latter is reduced by the color to about the same. If the distance which separates the lights be great, and if, as usually happens, the catoptric apparatus be the farthest off, it may be necessary either to use a larger reflector so as to increase the brilliancy by a greater concentration of the luminous rays; to place two or three in juxtaposition; or, finally, to employ a lenticular apparatus of the kind shown on figures 7, 8, 9, and 10 of Plate 12.

Thus the light-house of Pontaillac, which, in conjunction with that of Terre Nègre, distant two miles, marks one of the passes at the mouth of the Gironde, is alternately red and white, three reflectors being used for the red and two for the white light. It only illuminates an arc of about twelve degrees.

It is thus seen that the solution of the question of marking a certain direction by lights depends essentially upon local circumstances, and each particular case should be thoroughly studied. It is all important to remember that a leading or range line is more sensitive in proportion as the lights are farther apart, and that we should always keep within the limits already laid down, unless the necessities of the case require a departure. All of our leading lights are greatly within these limits, as it is easy to see by an inspection of the charts.

# CHAPTER II.

## ILLUMINATING APPARATUS.

The illuminating apparatus of a light-house is composed essentially of two distinct parts:
1st. The luminous focus.
2d. The optical system designed to direct toward the maritime horizon the rays of light which would diverge toward the sky, to the land side, or to the foot of the tower.

The apparatus now used are illuminated by lamps, and colza oil is the combustible usually employed.* They are divided into *catoptric* or *reflector* apparatus, and *dioptric* or *lenticular* apparatus. Both can be so arranged as to show colored lights.

We will examine, first, what the considerations are which govern the general arrangements of these apparatus and their accessories, after which we will describe the apparatus in most general use in the Light-house Service. We will conclude with a study of the different modes of producing light.

### I. CATOPTRIC APPARATUS.

Catoptric apparatus do not appear to have been applied to the illumination of light-houses until toward the close of the last century. There were some at that time upon a number of points on our sea-coast, among which we may cite Capes Ailly and La Hève, the isles of Ré and Oleron, and the tower of Cordouan. This latter dated from 1782, and though it had no less than eighty lamps, each with a reflector, the light was so poor that mariners earnestly requested a return to the preceding system of a coal fire, the latter having been substituted for a wood fire some years before. The apparatus, it is true, was very defective; the lamps had flat wicks, produced but little light and much smoke, and the reflectors, being segments of spheres, received but a small portion of the luminous rays, and did not transmit them in the most useful direction.

The chief engineer of the province, M. Teulère, who gained distinction at a later period by increasing the height of this same tower of Cordouan, was charged with the examination of the subject and the study of the means by which to remedy the evil. This resulted in the production of a very remarkable memoir, dated May 26, 1783, in which he exposed with great clearness the inefficiency of the system, and suggested the principal arrangements to which catoptric apparatus owe their value. He proposed that each reflector should be parabolic in shape; that it should be illuminated by a double-current-of-air lamp placed in the focus; that a number of reflectors should be pointed in the same direction, and, finally, that the apparatus should have a movement of rotation around a vertical axis, so as to throw in succession upon all points of the horizon the luminous beams emanating from the reflectors. In this way lights with eclipses were produced.

Borda has the credit, generally, of inventing parabolic reflectors and eclipse lights, and Argand of inventing double-current-of-air lamps.

But it was in 1784, after having heard of the memoir of Teulère from Marshal de Broglie, then minister of marine, that the learned academician caused to be constructed for the port of Dieppe, and without claiming the merit of the invention, a small revolving apparatus, consisting of five parabolic reflectors. The application of the new system to the tower of Cordouan was probably delayed for the reason that the question of raising the tower was at that time under consideration. The project for that important work was presented in 1786,

* Recently mineral oil has been introduced, and is used for lights of all orders.

and was immediately put in execution. Borda then engaged to make the apparatus invented by Teulère, who could not find at Bordeaux an artizan sufficiently expert for this work.

As to the inventor of the double-current-of-air lamp, it is to be remarked that the authors who attribute it to Argand, only go back to 1784 or 1786, while the memoir of Teulère bears date 1783. However, this engineer, who claimed to be the inventor of parabolic reflectors, does not insist upon that of the burner of the lamp. He contents himself with saying that Argand had the same idea as himself and made good use of it.

Without doubt the title of Teulère to priority may be contested. It would be very strange if no one before him had thought of utilizing, for the transmission of light, the well-known property of the parabola, and it appears that a small revolving apparatus of three reflectors (probably spherical shells) had been placed at the entrance of the port of Marstrand, in Sweden, prior to 1783.* But the French engineer invented, and is entitled to the credit of first devising, a system complete and rational in all its parts. He was the real inventor of catoptric lights in that sense, as they were very defective in every respect when he took up the study of the subject, and nothing essential has been added to his conception. Except the proportions and some few details of construction, the catoptric apparatus now in use are exactly similar to those of Teulère.

But it was not at the Cordouan that the new system was applied for the first time. It had already been experimented with successfully at other points on our sea-coast when, in 1790, the largest catoptric apparatus which had been constructed up to that date was placed upon the summit of the tower which Teulère had just completed. This apparatus consisted of three groups, each of which was formed of four reflectors, ranged above each other, facing in the same direction. These groups, set at angular spaces of 120° so as to divide the circumference into three equal parts, were supported upon a frame of the form of a triangular prism, to which a motion of rotation was given by clock-work mechanism. The flashes followed each other at intervals of two minutes. The reflectors had thirty inches (0.812 of a meter) opening. Illuminated at first by lamps, the burners of which were too small, they gave little divergence; the flash was very bright, but it only continued during five seconds. In 1793 the diameters of the burners were increased, and the duration of the flashes then reached ten seconds.

About the same time, Teulère caused to be set upon the light-house of Chaume, at the Sables d'Olonne, an apparatus composed of only three reflectors, in the focus of each of which was a burner of 0.033 of a meter diameter.

This mode of illumination was a great improvement on the old system. It was eagerly adopted by maritime nations, and until within a recent period it was exclusively used on the coasts of England, as well as upon those of most of the maritime powers of the north of Europe.

Catoptric apparatus now in use.

The catoptric apparatus now used in the Light-house Service of France are composed of one or several parabolic reflectors, each with a double-current-of-air lamp fed by colza oil. These reflectors are of two kinds: one, often called the *photophore*, has but one nappe, and its surface may be generated by the revolution of a parabola around its axis, as those of Teulère; the others have two nappes, the surfaces of which may be generated by the revolution of a parabola around a line passing through its focus and perpendicular to its axis. The latter were invented by Bordier Marcet, and named by him *sideral apparatus*. Figures 11, 12, and 13 of Plate 12 represent a *photophore* mounted upon its stand, and Figures 14 and 15 of the same plate show a *sideral apparatus* inclosed in a portable lantern.

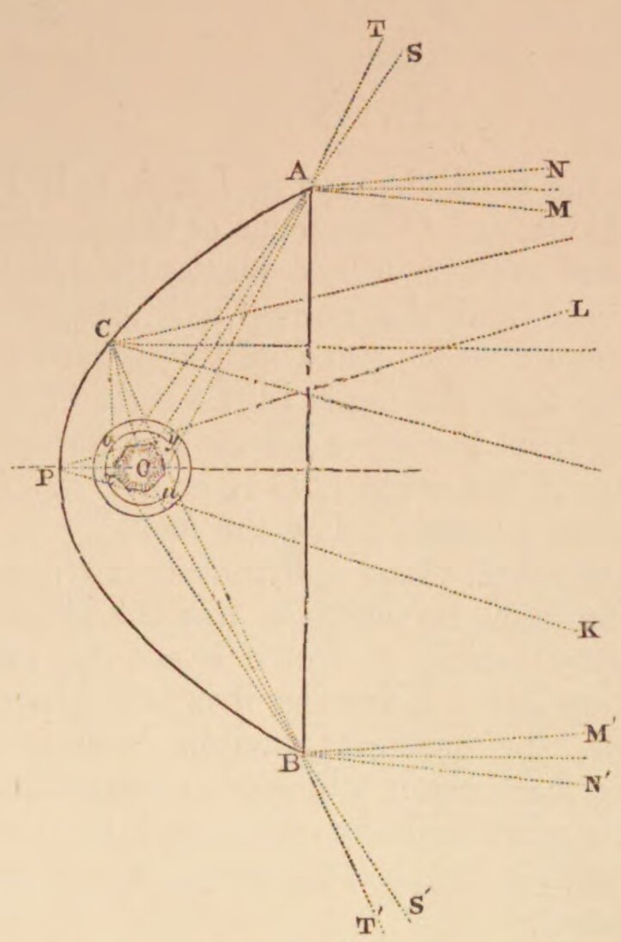
Parabolic reflectors of one nappe.

It is seen from an inspection of figure 6, annexed, that the photophore concentrates into a single beam all those rays comprised in the angle O A P B, which, leaving out of consideration the losses due to the absorption by the metallic surface, and the occultation produced by the burner of the lamp, constitute the greater part of the rays emitted from the focus O of

* Lavoisier, as early as 1775, discussed in a memoir the advisability of using parabolic reflectors for lighting the streets of large cities.—P. C. H.

the paraboloid. The direct rays included in the angle A O B diverge and form a luminous cone, the upper part of which is of no use for illumination. If the luminous focus were reduced to a point, all the reflected rays would be parallel to the axis, and the transverse section of the beam of light would be at all distances precisely equal to the opening of the photophore; but such is not the case; the illuminating body, as compared with the reflector, has notable dimensions, and each point of the illuminating surface reflects a conical beam, the divergence of which is greater in proportion as the reflecting point is nearer the focus and the flame larger. The beam, therefore, which proceeds from the reflector is not cylindrical but conical. Besides, the luminous rays are not equally distributed throughout the entire extent of the cone, as it is easy to see by observing the directions they take after having been reflected.

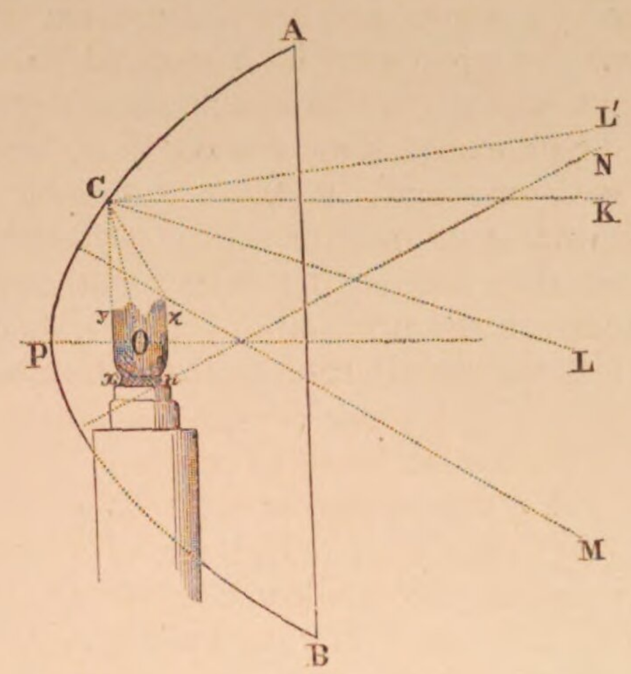
FIG. 6.




Let *u x y z*, Figure 6, be the horizontal section of the flame; the most divergent rays in the horizontal plane are those which, tangent to that circumference, meet the reflector at its vertex P, and the angle L P K represents the horizontal divergence of the apparatus. The extreme rays, such as *z* A and *u* A, are reflected along the lines A M and A N, which form with the axis of the parabola angles equal to each other, and to the angles *z* A O and O A *u*. The angle of divergence of these luminous rays is equal to M A N. The divergence produced by any other point, as C of the reflector, is determined in the same manner. This divergence is precisely equal to the angle which is included between the tangents drawn from that point to the circumference of the flame. In the horizontal plane, beyond the point where the lines A N and B N, intersect the lines P L and P K, the angular space L P K embraces all the reflected rays; to the right and to the left is an angular space comprised between the lines L P and S *z*, or K P and S′ *x*, in which the rays coming direct from the focus are seen; finally, in the angles S A T and S′ B T′, we find but a part of these rays, the number of which diminishes as we leave the lines A S and B S′, and disappears at A T and B T′.

In the same way, the course which the luminous rays take in any plane whatever may be ascertained.

FIG. 7.




Let us take for example the vertical plane. Let A P B, Figure 7, be the section of the reflector, *x y z u* that of the flame, and O the focus of the paraboloid. The ray *z* M, proceeding from the point *z*, and normal to the parabola, marks the limit of the divergence of reflected rays below the horizontal plane, and the normal *u* N, drawn from the point *u*, limits the divergence above the same plane. Any point C of the upper part of the reflector sends below the horizon all the rays coming from the flame to the right of the line O C, and reflects above that plane all the rays coming from the other side. The former are comprised in the angle L C K = O C *z*, and the latter in the angle L′ C K = O C *x*. The inverse effect is produced by all the points of the parabola situated below the focus.

The divergence in the horizontal plane and that below it are useful to the illumination; for, while it diminishes the luminous intensity, it has the effect of spreading the light over a greater surface, which is no disadvantage. But it is not the same with the rays sent above the horizon; they are absolutely lost. However, it is less important to utilize all the reflected rays than to throw the light the greatest possible distance; to direct the most intense luminous beam tangentially to the horizon, which is accomplished by placing the flame at such a height that the center of its most brilliant horizontal section will be in the focus of the paraboloid. This arrangement has, besides, the advantage of sending more of the rays below than above the horizontal plane.

When the apparatus is greatly elevated above the level of the sea, it is inclined downward so that its axis prolonged will be tangent to the horizon; but, in most cases, the height is not such as to render it necessary to resort to that measure, as the tangent to the horizon is sensibly horizontal.

The reflectors of one nappe, which are still used for some of our illuminating apparatus, are of three sizes. Those taken out of the old light-houses since the invention of the lenticular system are generally called *Lenoir reflectors*, from the name of the maker. They have an opening of 0.85 of a meter, with a depth of 0.345 of a meter, and a focal distance of 0.131 of a meter.

They are generally lighted by lamps with burners of 0.024 of a meter diameter, consuming about 60 grammes of colza oil per hour, the intensity of which is equivalent to 1.60 carcel burners. Recourse is had to lamps with two concentric wicks when circumstances render it necessary to have greater brilliancy and at the same time greater divergence. The burners of these lamps have a diameter of 0.039 of a meter. They consume 175 grammes of colza oil per hour, and their intensity may be estimated at five carcel burners. The divergence of the reflected rays in the horizontal plane is about 12° when the lamp has but one wick, and 18° when it has two.

Other parabolic reflectors of one nappe have an opening of 0.50 of a meter, depth 0.195 of a meter, focal distance 0.08 of a meter, and are illuminated by lamps with one wick 0.024 of a meter in diameter. Their divergence in the horizontal plane is about 20°.

The reflectors now in most general use have an opening of only 0.29 of a meter, and a depth of 0.125 of a meter. Their focal distance is 0.042 of a meter. They are for the most part illuminated by lamps with one wick 0.021 of a meter in diameter, consuming 50 grammes of colza oil per hour, and of an intensity estimated at 1.30 carcel burners. Inferior to the preceding in useful effect, they are, on the other hand, lighter, more easily placed, and less expensive. Their divergence in the horizontal plane is about 36°.

Distribution of the luminous rays.

The following table exhibits the distribution in the horizontal plane of the luminous rays by these different apparatus. The Light-house Service has adopted these figures as representing with sufficient accuracy the intensities found in practice. They are deduced from numerous experiments, not free from some anomalies, as might have been foreseen from the irregularities of form which are found in nearly all reflectors. The *maxima* found in these trials have been reduced about $\frac{1}{6}$, so as to make allowance for the want of proper care when in actual use, and the absorption of the luminous rays by the glass of the lantern:

| Degrees from the axis. | Intensities, in Carcel Burners, of Parabolic Reflectors— | | | |
|---|---|---|---|---|
| | Of 0.85*m.* opening, with a lamp equal to 5 carcel burners. | Of 0.85*m.* opening, with a lamp equal to 1.60 carcel burners. | Of 0.50*m.* opening, with a lamp equal to 1.60 carcel burners. | Of 0.29*m.* opening, with a lamp equal to 1.30 carcel burners. |
| 0 | 760 | 550 | 200 | 60 |
| 1 | 752 | 540 | 196 | 60 |
| 2 | 715 | 470 | 185 | 59 |
| 3 | 640 | 315 | 166 | 57 |
| 4 | 515 | 150 | 140 | 54 |
| 5 | 360 | 40 | 110 | 50 |
| 6 | 220 | 5 | 75 | 44 |
| 7 | 100 | ..... | 46 | 37 |
| 8 | 30 | ..... | 25 | 30 |
| 9 | 5 | ..... | 10 | 22 |
| 10 | ..... | ..... | 4 | 16 |
| 11 | ..... | ..... | ..... | 12 |
| 12 | ..... | ..... | ..... | 9 |
| 13 | ..... | ..... | ..... | 7 |
| 14 | ..... | ..... | ..... | 5 |
| 15 | ..... | ..... | ..... | 4 |
| 16 | ..... | ..... | ..... | 3 |
| 17 | ..... | ..... | ..... | 2.5 |
| 18 | ..... | ..... | ..... | 2 |

The brilliancy in the axis, and the divergence in the horizontal plane of a reflector of 0.85 of a meter opening, illuminated by a two-wick lamp, consuming 110 grammes of colza oil per hour, with an intensity equal to 3 carcel burners, may be estimated respectively at 580 burners and at 16°.

Advantages of parabolic reflectors.

Parabolic reflectors possess the advantage of being lighter and less expensive than lenticular apparatus. For the following purposes they are well adapted and are frequently used:

1st. For the illumination of narrow passages, or to form one of the leading lights of a channel.

2d. To reinforce in a given direction the intensity of a light the range of which is sufficient in other directions; in this way a small parabolic reflector was placed in the lantern

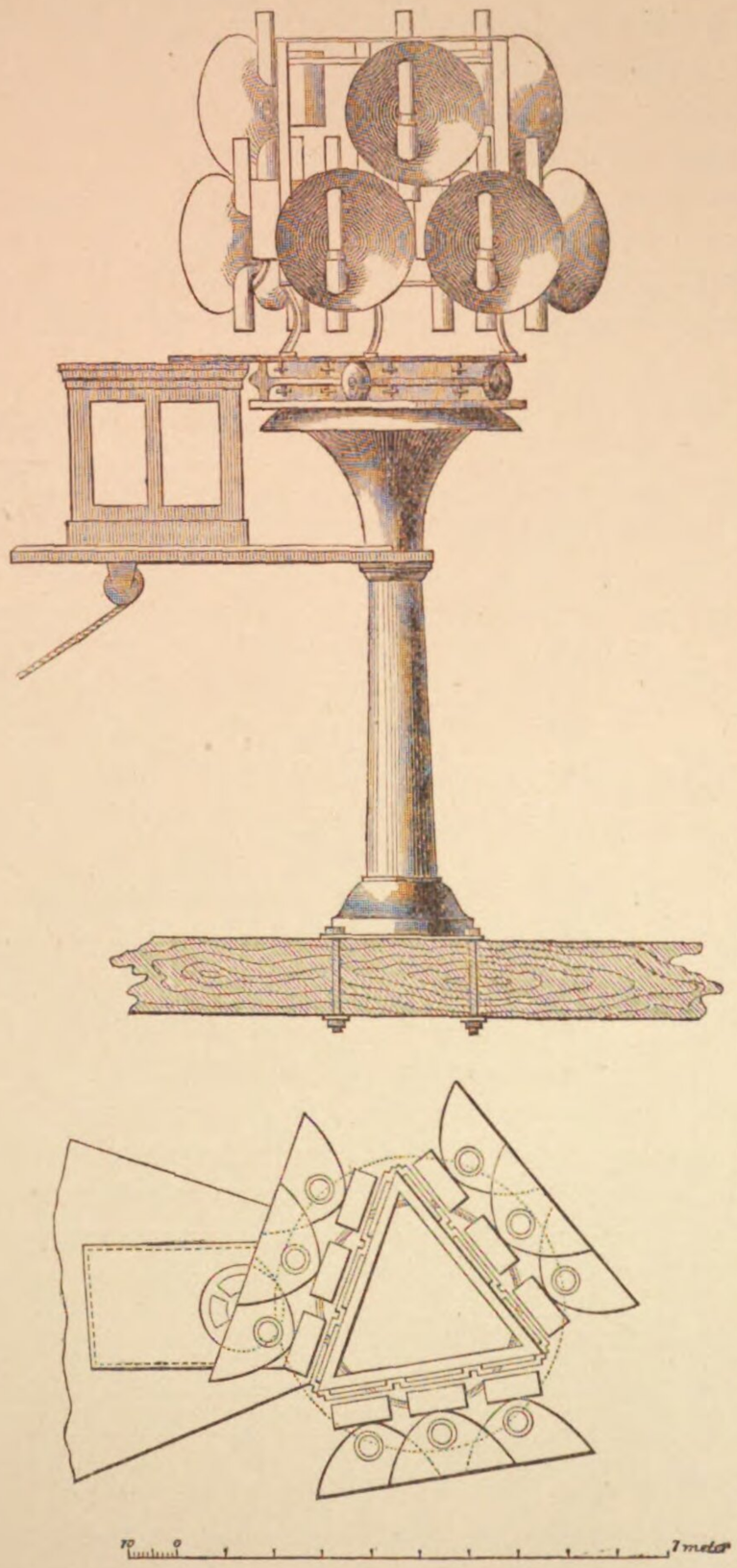
of the light-house at Terre Nègre to increase the intensity of the light in the direction of the north pass of the mouth of the Gironde.

3d. For floating lights. The lenticular apparatus may also be used for this purpose, but they are better adapted for fixed structures.

4th. For temporary lights.

Such an apparatus is represented in plan and elevation by Figure 8. It is composed of

FIG. 8.

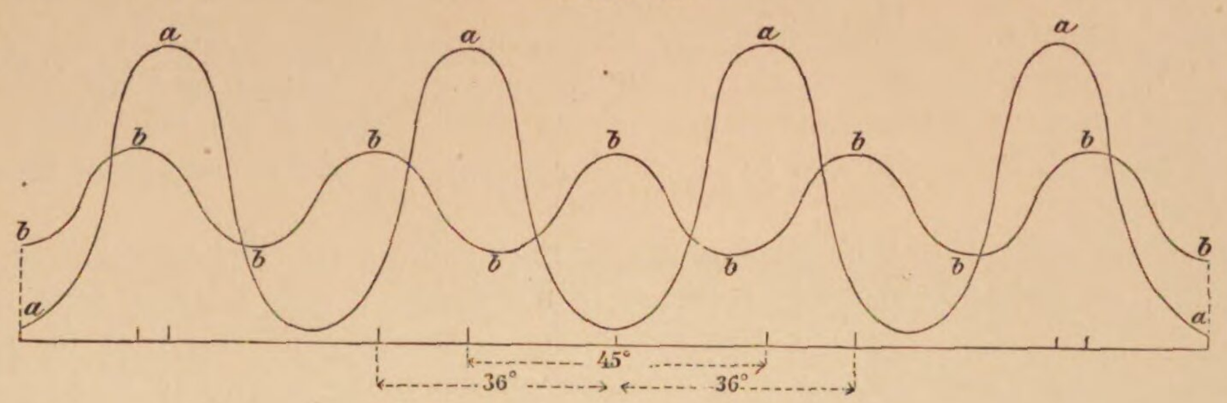



nine reflectors grouped in threes. A small clock-work machine revolves it, and eclipses occur more or less frequently, according as the motion of rotation is more or less rapid. The range of this apparatus is about 15 miles.

Parabolic reflectors are better adapted for eclipse than for fixed lights designed to illuminate the whole or the greater part of the maritime horizon. In the first case the same luminous beam is transmitted in succession to every point of the horizon, so that the range is the same in every direction, while, on the other hand, to obtain a uniform distribution of light in every

part of the circle to be illuminated would require the use of a much greater number of reflectors. This last point, however, is of little importance when it is a question of illuminating a narrow channel, because there is generally an advantage in directing the greater part of the luminous rays along its axis. But this is not the case under ordinary circumstances. Thus the illuminating apparatus on light-vessels showing fixed lights, as most of them do, are required to illuminate the entire horizon, and are formed by a series of reflectors of 0.29 of a meter opening, arranged in a circle inside of a lantern which encircles the mast on which it is hoisted. The first apparatus of this kind made in France consisted, like those of England, of only eight photophores, set with their axes at equal angular distances from each other; the result was that the observer perceived a brilliant light when in the axis of one of the reflectors, and only saw the unreflected light coming from two foci when he was midway between the axes of two contiguous reflectors. Within an angular space of 36° the luminous intensity varied from 2 to 60 burners; between these spaces there are others of 9° within which the light was uniformly distributed, the intensity being no more than 2 burners.

FIG. 9.




The curve *a a a* of Figure 9 shows the variations in the appearance of the light emanating from such an apparatus.

It is constructed by taking for abscissæ the angular spaces to a scale of 0.01 of a meter to 15°, and for ordinates the luminous intensities to a scale of 0.01 of a meter to 20 burners.

A more equal distribution of the light would be obtained by increasing the number of reflectors, because then the reflected rays from two contiguous reflectors can be made to cross each other. With 24 reflectors the luminous intensity from one point to another can be regulated so as not to vary more than from 67 to 68 burners, which may be considered as practically uniform The intensities would not differ in too great a measure if but 16 reflectors were used Their maximum would be 60 and their minimum about 25 burners.

Such a large number of reflectors would require a lantern of such a size that it could with difficulty be used for floating lights, and would consume an amount of oil far beyond that of ordinary lights of the same range.

The fixed light apparatus for the light-vessels recently established at different points on our coasts consist of 10 reflectors, each illuminated by a lamp with one wick 0.021 of a meter in diameter, consuming 50 grammes of oil per hour, the flame of which was placed, not at the focus of the reflector, but 0.01 of a meter nearer the vertex of the parabola, so as to give greater divergence. The curve *b b b* of Figure 9 shows how one of these apparatus distributes the light in the horizontal plane. The ex-focal position of the burner of course reduces the intensity in the axis of the reflector very much. The maximum intensity in this case is only 38 burners, but the minimum is no less than 18, which is sufficient for the height of the apparatus above the level of the sea. Plate 13 represents an apparatus of this description.

The vertical divergence of these apparatus is also greater than if the flame were at the focus of the paraboloid; but it has the advantage of preventing the occultations which the motion of the vessel tends to produce. The luminous rays which are uselessly thrown up toward the sky when the vessel is at rest are sometimes usefully brought to the horizon by

the motion communicated to the reflectors, as they do not always retain their normal position, notwithstanding the system of suspension employed.

Lenticular apparatus might be substituted for parabolic reflectors, and the oil thus economized. But the advantages to be derived do not appear to be of sufficient importance to off-set the inherent disadvantages of the system, and the studies which were commenced with a view to introducing it have not been followed up.

In eclipse-light apparatus for floating lights not more than eight reflectors are used, and they are sometimes so grouped as to produce very brilliant flashes. The apparatus recently constructed for one of the light-vessels off Dunkerque is composed of eight reflectors of 0.37 of a meter opening, 0.185 of a meter depth, and 0.047 of a meter focal distance, the flames being at the foci. It is represented on Plate 14.

If it be desired to employ reflectors for the illumination of a light-house with a fixed light which is required to illuminate with considerable brilliancy a large portion of the horizon, it will be necessary not only not to give an ex-focal position to the burner, as in the case of fixed lights for light-vessels, but also to use large reflectors similar to those of Lenoir, so as to reduce the divergence above the horizontal plane as much as apparatus of this sort will allow.

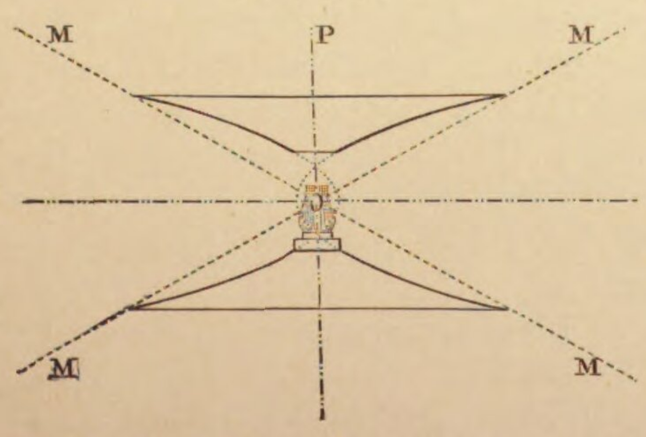
It is unnecessary to examine into the arrangements which might be adopted for this purpose, for they vary according to the circumstances of each case, and are, besides, easily imagined. No apparatus of this kind is now in use on the coast of France; those which were formerly used have all been replaced by lenticular apparatus, to the benefit of navigation and the public treasury.

Still, there are cases in which circumstances may render the employment of these large reflectors useful; for instance, if it be necessary to illuminate a long channel within an angular space of 12° or 15°. The light at Pontaillac, for instance, was required to do this, and, besides, to have such a characteristic as would prevent its being mistaken for any of the other lights at the mouth of the Gironde. It was composed of three 0.85 of a meter reflectors, the axes of the reflectors being in prolongation of the axis of the channel. Two of them were provided with single-wick lamps, and the third with a double-concentric-wick lamp and a red chimney. By means of clock-work a screen first masks the colored light, then, this being uncovered, a red pane of glass is placed before the other two. The shifting is rapid, and takes place at regular intervals of 20 seconds, so that the light appears alternately red and white during that interval of time, without intervening eclipses. There was some thought of having the red light revolve instead of having it masked, in order that the rays which are lost while the white light is shown might be utilized in another direction; but local circumstances did not seem to warrant the expense of such an arrangement.

Sideral apparatus.

In the sideral apparatus the luminous rays are uniformly distributed around the horizon, except those sent back by the lateral reflectors, to be spoken of hereafter. If the luminous focus were reduced to a point, the only rays lost, except those absorbed by the reflecting surface, would be, as shown on Fig. 10, the direct rays comprised between the horizontal

FIG. 10.




plane passing through the focus, and the conical surface generated by the rotation of the line O M round the vertical axis O P. But as, in the ordinary reflectors, the loss is in proportion

to the dimensions of the illuminating body; it is easy to determine it by following the process before adopted, and it is, therefore, unnecessary to pursue the subject further.

Whenever a sideral apparatus is not required to illumine the entire horizon, and that is usually the case, the cistern of the lamp is placed in the dark angle, and on each side of it parabolic reflectors, which unite with the two nappes of the apparatus and utilize the luminous rays which diverge to the land side.

These apparatus are made only of small dimensions, and have but short range. Their brilliancy does not exceed about 3½ burners.

They are usually placed in small movable lanterns, which can be hoisted upon a wooden frame, or upon a lantern-post between guide-rods.

Sideral apparatus, on account of their lightness and cheapness, came at one time into use to some extent for light-house purposes on our coasts; but the small dioptric apparatus of cast or cut glass, which will be noticed hereafter, are preferable in every respect, and no new ones have been established.

Construction and care of reflectors.

All reflectors are made of sheets of copper, shaped in a mold, and plated with silver. They lose a great deal of their reflecting power when tarnished, or when not kept perfectly clean. Either of these defects, though not very marked, will reduce the quantity of light emanating from the apparatus about one-fifth. The instructions for the service of lights show how these apparatus should be cared for.

## II. DIOPTRIC APPARATUS.

As convex lenses possess the property of refracting in a direction almost parallel to their axes all the rays of light emanating from their foci, they may be used for a purpose analogous to that of the parabolic reflectors; but while their outside surfaces retained their ordinary continuous spherical form, they could not be applied to the illumination of light-houses. Constructed necessarily of large dimensions, they would have been very thick in the middle; and thence would arise three grave difficulties—great absorption of the luminous rays by the lens itself; more or less deviation of rays in consequence of air-bubbles, striæ, or differences of density in the glass itself; and such weight as would render it difficult to make a good arrangement of the parts of the apparatus.

Lenses in echelon.

Buffon made the first advance toward overcoming the difficulties, and, though not thinking of maritime illumination, he proposed to make lenses in echelons or steps. He supposed that they would be formed of a single piece of glass, and did not discover the means by which a good use might be made of the echelon arrangement to direct the luminous beams in the most satisfactory manner. The invention was neither practical nor complete, and it had been long forgotten, when, in 1819, Augustin Fresnèl, a young member of the Corps of Engineers of Bridges and Roads, well-known already as a scientist, was attached to the Commission of Lights. Without suspecting that the invention was not new, he caught the same idea that Buffon had previously conceived, viz, that the lenses should be in echelon; but he did not stop there; he saw at once that, that form could be applied so as to correct spherical aberration, a defect which is greater as the lenses are larger; he recognized all the various ways in which the new system could be employed, and devised the means for carrying them out, leaving to a not distant future the care of perfecting them.

His lenses were composed of one central piece surrounded by concentric annular prisms, cast and ground separately, and afterward solidly joined together.

A section through the axis gives on one side a straight line (lens being plano-convex, so as to render its manufacture more easy) and on the other circular arcs, the radii, the centers, and the amplitudes of the arcs being so calculated as to reduce as much as possible spherical aberration and the thickness of the glass.

Arrangement of the lenses.

The profile or section through the axis being decided on, two systems of lenses naturally follow:

1st. In giving the section a movement of rotation around the horizontal axis passing through the focus, a lens of annular elements is generated, possessing, in common with parabolic reflectors, the property of uniting in one beam all the luminous rays emanating from the focus. Let several of these lenses be placed so as to form a prism with a polygonal base, having for its axis a vertical line passing through their common focus; place a light at that point, and turn the lenticular drum thus formed around its axis: the luminous beams emanating from the lenses will thus be thrown in succession on all points of the horizon, and no light will be seen in the intervals between them. We shall thus have an eclipse-light apparatus

2d. If the same section of the lens be revolved around the vertical axis passing through the focus, a cylinder will be generated, and a lens of this form will distribute uniformly upon the entire horizon the luminous rays which emanate from the focus. This constitutes a fixed-light apparatus.

**Lenses with vertical elements.**

The figure of a third kind of lens, sometimes used, is obtained by moving the section parallel to itself in a vertical plane; this movement generates a lens with a plane on one side and vertical prismatic elements on the other. Such a lens has the property of uniting all the rays emanating from the focus in a beam comprised between two vertical planes. It is easy to see, that by properly placing a lens of this description in front of a cylindrical lens, it will collect the diverging rays into one beam, as is done by an annular lens. The first renders the rays horizontal; the second renders such of the horizontal rays as pass through it parallel. Although it doubles the number of lenses and is not favorable to economy of light, this arrangement is sometimes employed to produce fixed lights varied by flashes, as we shall see further on. Figures 1 and 3 of Plate 6 show an apparatus of this description.

**Height of the lenses.**

The height of the lenticular drum ought to have a certain relation to the focal distance. There is a limit beyond which there would be loss, by reflection upon the interior face of the lens, of a notable portion of the luminous rays, and, besides, the salient angles of the echelons the farthest from the center would become so sharp that it would be difficult to make them, and when made they would be extremely liable to be broken. The angle which the drum of the apparatus subtends at the focus was fixed at first at 45°, but it was found that it might with advantage be made greater. It varies now from 56° to 67°, according to the nature of the apparatus.

**Arrangements with reference to the rays passing above or below the lenticular drum.**

The rays passing below the drum would unnecessarily light the vicinity of the foot of the tower; those rising above it would be lost in space, and consequently be of no use to maritime illumination if some arrangement were not devised to direct them to the horizon.

Different arrangements were conceived by Augustin Fresnel with the view to utilizing these portions of the emitted light.

In 1822, in the first large apparatus which he had constructed, and which was placed upon the Cordouan tower, eight small lenses, having a focal distance of 0.50 of a meter, forming a kind of canopy above the lamp, collected the upper luminous rays and transmitted them in beams upon large plane mirrors placed to reflect them to the horizon. The apparatus was for an eclipse light and had eight panels. Its upper part revolved with the drum, but its panels, instead of being placed so that the axes of the two were paralle , were so established that one flash slightly preceded the other. The additional light obtained by this upper system of lenses could have been employed to augment the intensity of the flashes; it was preferred, and with good reason, to use it to prolong their duration.

The rays passing below the drum form but a small part of the light emitted from the focus, and Fresnel did not at first attach much importance to utilizing them. However, he announces in a note, placed at the end of his memoir of 1822,* that they could be directed to the horizon by means of small plates of silvered glass fixed below the lenses, and *arranged like the leaves in a window-blind*, with the proper inclination to reflect the rays in the desired direction. The idea was carried out in several apparatus, but the small mirrors, being plane surfaces, only solved the problem approximately.

*See this important work. Document No. 2.

Some years afterward, these slabs or leaves were replaced by horizontal zones formed of curved plated mirrors, and zones of the same kind were substituted for the movable apparatus above the drum. The mirrors in each of these zones, which were set closely one above the other, could be considered as surfaces generated by the revolution of an arc of a parabola, having its focus in that of the apparatus, around a vertical line through the same point.* The luminous rays collected by them were no longer used to prolong the duration of the flashes in flashing lights; they were distributed uniformly over the entire horizon, and produced a fixed light which could be seen during the eclipses, thus enabling mariners to keep the light always in view while approaching the coast. In light-houses with fixed lights these parabolic mirrors increased the intensity of the light. The arrangements adopted above and below the drum were then the same for all lights.†

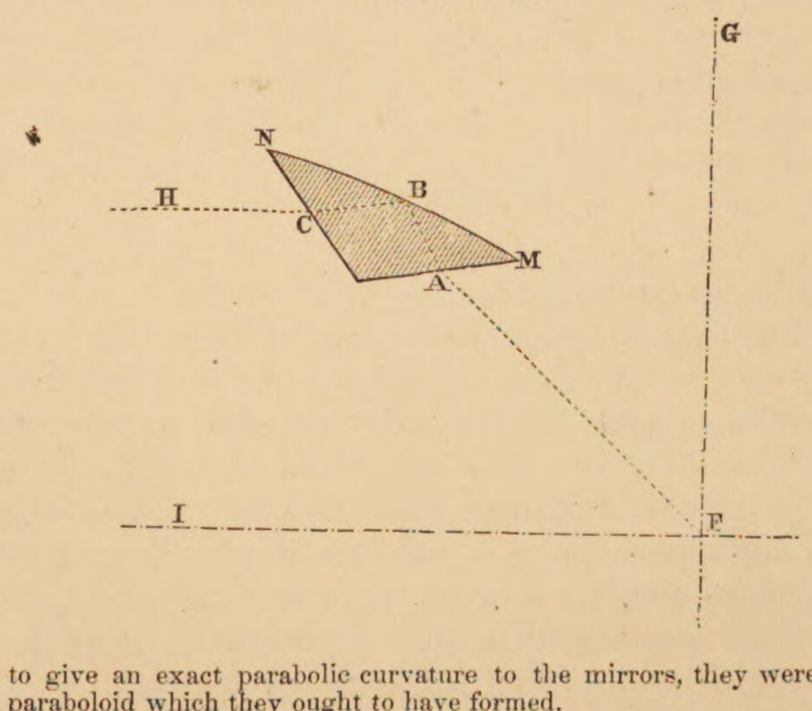
This arrangement for utilizing the light that would otherwise pass out above and below the dioptric drum, though very good in theory, failed to give the best results in practice. The mirrors, even when new, did not reflect the light nearly as well as the lenses refracted it, and their reflecting powers diminished greatly when the silver plating became worn. They were liable to become deranged in position by the necessary cleaning, and the keepers were not always careful to replace them properly; finally, their construction was so difficult that the engineers were obliged to be very tolerant in receiving them, and the price, though very high, was not considered sufficient by the constructers.

Catadioptric rings

An entirely new and faultless arrangement was conceived by the illustrious inventor of the lenticular system; it consisted in transmitting the rays to the horizon by refraction and total reflection by means of glass rings triangular in section. But theoretical conceptions cannot always be immediately put in practice The fabrication of the lenses had proved this. Before it was practicable to obtain for them the regular forms which are given by the machinery now in use, it became necessary to make them polygonal in shape, and to build them up of a series of small spherical segments ground in an oculist's basin. The new rings could not be made in the same way, and he was compelled for a long time to confine their use to the small apparatus, the grinding of which did not require too expensive machinery.‡

Figure 11 shows the course of a luminous ray through a section of one of these rings.

FIG 11.




*As it was impossible to give an exact parabolic curvature to the mirrors, they were shaped like the osculatory spherical surface of the fragment of the paraboloid which they ought to have formed.

†This system, although still to be found in actual use in some light-houses, has been abandoned. It is therefore thought to be unnecessary to represent it upon a special plate.

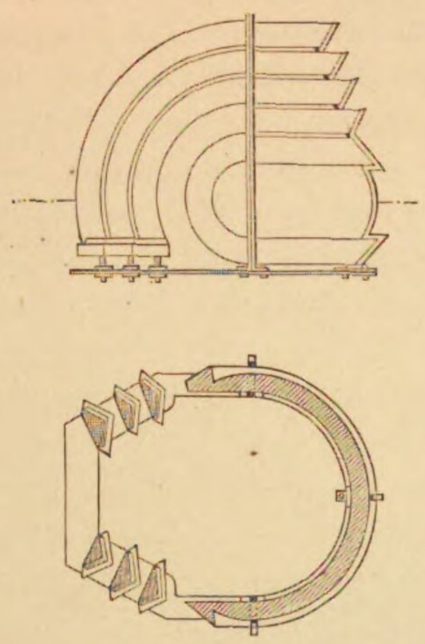
‡The fixed-light apparatus of the Gravelines light-house was the first one of the third order to which catadioptric rings were applied, and its construction bears the date 1842; the following year they were applied to fixed lights of the first order. It was not until 1852 that annular catadioptric panels for apparatus of the first order were for the first time constructed. They were made by Mr. Henry Lepaute for the light-house of Ailly, and were employed to prolong the duration of the flashes.

Starting from the focus F, it is refracted at A, follows the direction A B, becomes totally reflected on the surface M N, takes the direction B C, and at last leaves the ring following the horizontal line C H.

The profile of the catadioptric rings being given, it may, as in the case of the lenses in echelon, receive a motion of rotation either around the vertical axis F G, passing through the focus, or around the horizontal axis F I, drawn through the same point. In the first case it distributes the light uniformly around the entire horizon, and constitutes an element of fixed-light apparatus; in the second, it unites all the rays into one beam, after the manner of the lenses employed in the eclipse-light apparatus. The application of these two principles were made during the lifetime of Augustin Fresnel, but only to small apparatus—the first to the fixed-light apparatus of the kind represented by Figures 1, 2, 3, and 4 of Plate 12, and both at one time to the smaller apparatus which were employed for a time for lighting the St. Martin's canal at Paris. The front part of the latter distributed the light equally over one-half of a circle in the same manner as a fixed-light apparatus of 180°, and was prolonged at each extremity by a half-lens, part dioptric and part catadioptric, which produced a luminous beam, comparatively intense, directed normally to the meridian plane of the apparatus. Thus were found united on a small scale, and for a useful purpose, the two principal systems of panels of both kinds of profiles. There is in it almost a complete summary of the valuable invention.

Figure 12 represents one of these apparatus, which is religiously preserved, in the Museum

FIG. 12.



of the Commission of Lights, among types of the most ancient lenses. It shows the side elevation, and the horizontal section taken at the height of the focal plane.

The essential principles were established. The just praise which the French illuminating apparatus obtained, the development which all the maritime powers wished to give to the illumination of their coasts, favored the new invention, encouraged our constructers, and enabled them to erect establishments for their manufacture upon a large scale, and develop continued improvements in the apparatus. Mirrors are now no longer made, and catadioptric rings are applied in different forms to the largest apparatus.

Spherical reflectors.

When an apparatus is not required to illumine the entire horizon, it is important to direct to the sea the rays which would diverge uselessly toward the land side. For that purpose recourse is had to spherical reflectors, which cover the dead angle of the apparatus and return to the focal point the rays which come in contact with them. These reflected rays, pursuing their course, strike the lenses opposite, which refract them in the same way that the others are refracted. However, it is not upon the exact focus that the reflected rays cross each other; it is a little higher, for the center of the spherical reflector is placed slightly above

that point. There are two reasons for the adoption of this arrangement: First, if the center of the spherical surface of the reflector coincided with the focal point a large part of the reflected rays would be arrested by the body of the lamp; second, the burner would become heated, liable to be fused, and the wicks charred.

The consequence is, that the greater part of the reflected rays are transmitted through the lenses on lines more or less inclined to the horizon, and they increase the brilliancy of the light in a much greater proportion at a short than a long distance. It is readily seen that there would not be any economical advantage in substituting for these reflectors much more expensive apparatus, even though there might be less absorption of the luminous rays, such as can be made by means of double-reflecting catadioptric rings. Expense cannot be left out of the question in such cases.

In some apparatus of the first order the reflectors have been placed on the land side not only to the height of the drum, but also both above and below it. That arrangement has been abandoned for the reason that the quantity of light gained thereby was not thought to be sufficiently great to compensate for the expense of placing them; besides, it has been found that it is not without advantage in the supervision of the service to allow a little light to be transmitted landward.

These reflectors are usually made of sheets of copper plated with silver. One of our constructers, Mr. L. Sautter, makes them of glass, silver plated on the exterior surface. A much better polish is thus obtained, while at the same time they are much easier cleaned; the shape, however, is perhaps not as regular.

Dimensions and intensity of the flames.

In catoptric apparatus the number of lamps must be increased in proportion as the power of the light is increased; in lenticular apparatus we operate on the lamp itself, and for this purpose the number and the diameter of the wicks are made to vary. The dimensions of the apparatus are regulated according to those of the flame.

The diameters of, and the spaces between the wicks now in use were decided on in 1821 by Fresnel and Arago, and the long experience to which they have been subjected since that time has fully justified their decision. They were so established as to insure regularity of service and to allow the oil to be used to the best advantage.

Orders of lights.

The lamp burner of first-order lights has four concentric wicks; that of the second order three; that of the third order two; and all the apparatus illuminated by a lamp of a single wick are ranked as the fourth order.

Plate 15 represents these burners and the flames generated by them, on a scale of one-half. The burners are seen in elevation on one side, and in vertical section on the other.

The following table shows the regulation dimensions, and the luminous intensities of the flames:

| Order of light. | No. of wicks. | Dimensions of the fully developed flame. | | Luminous intensity in carcel burners. | Numbers of the corresponding figures on Plate 15. |
|---|---|---|---|---|---|
| | | Maximum diameter. | Height above the burner. | | |
| | | *mm.* | *mm.* | | |
| 1st order | 4 | 90 | 100 | 23 | 1 and 2 |
| 2d order | 3 | 75 | 80 | 15 | 3 and 4 |
| *3d order, large model | 2 | 45 | 70 | 5 | 5 and 6 |
| *3d order, small model | 2 | 38 | 65 | 3 | ..... |
| 4th order, large model | 1 | 30 | 45 | 1.6 | 7 and 8 |
| 4th order, small model | 1 | 27 | 37 | 1.3 | ..... |

*The 3d order small model corresponds to the 4th order, the 4th order large model to the 5th order, and the 4th order small model to the 6th order in the United States.—P. C. H.

Dimensions of apparatus.

It is easy to see that it is necessary to preserve a certain relation between the dimensions of the lenticular apparatus and those of the flame which illuminates it, so as to maintain within proper limits the expense of the first establishing, and to make the best use of the light produced at the focus. Indeed, a certain amount of divergence is necessary, to insure the illumination of the entire surface of the sea and the proper duration of the flashes of eclipse lights; but if it be too great, a portion of the luminous rays will be lost and the intensity of the light will be proportionally reduced.

These considerations have caused the dimensions of the apparatus of the different orders to be fixed as shown by the figures of Plate 3 and the following table:

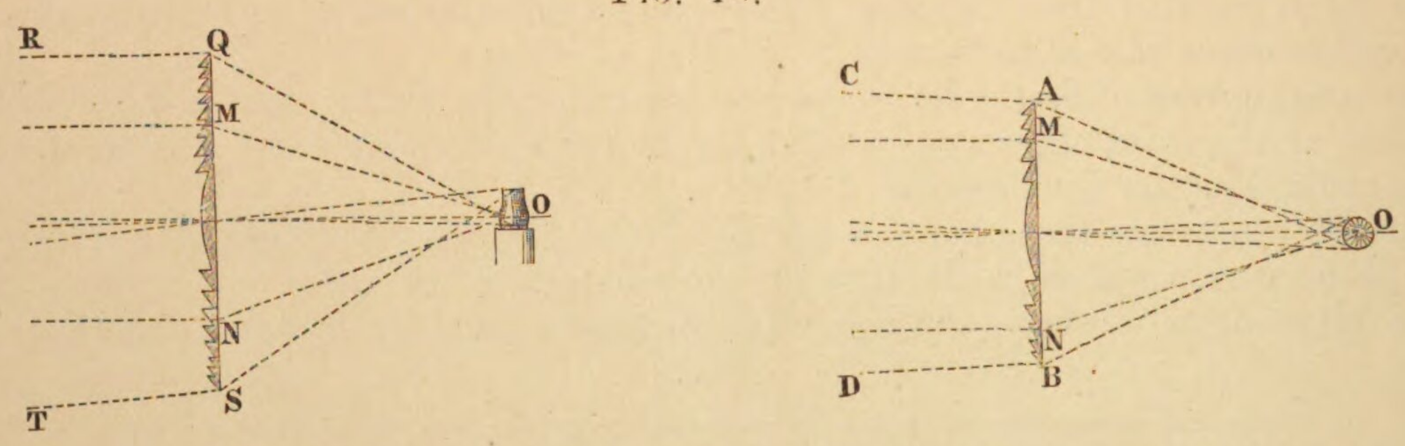
| Order of the apparatus. | | Interior diameter of the drum. | Height of the optical parts. | | | Total height, including the interior frames. | Corresponding figures of Plate 3. |
|---|---|---|---|---|---|---|---|
| | | | The lower part. | The drum. | The upper part. | | |
| | | *m.* | *m.* | *m.* | *m.* | *m.* | |
| 1st order | | 1.840 | 0.539 | 0.980 | 1.001 | 2.590 | 1 |
| 2d order | | 1.400 | 0.378 | 0.854 | 0.810 | 2.069 | 2 |
| 3d order | large model | 1.000 | 0.278 | 0.660 | 0.593 | 1.576 | 3 |
| | small model | 0.500 | 0.144 | 0 300 | 0.258 | 0.722 | 4 |
| 4th order | large model | 0.375 | 0.105 | 0.226 | 0.196 | 0.541 | 5 |
| | small model | 0.300 | 0.084 | 0.180 | 0.157 | 0.433 | 6 |

Distribution of the luminous rays.

Let us now examine the directions that the luminous rays take when transmitted from the flame to the different parts of a lenticular apparatus.

The following figures represent a portion of the plan and section of an eclipse apparatus of the first order, each panel of which embraces one-eighth of the circumference.

FIG. 13.



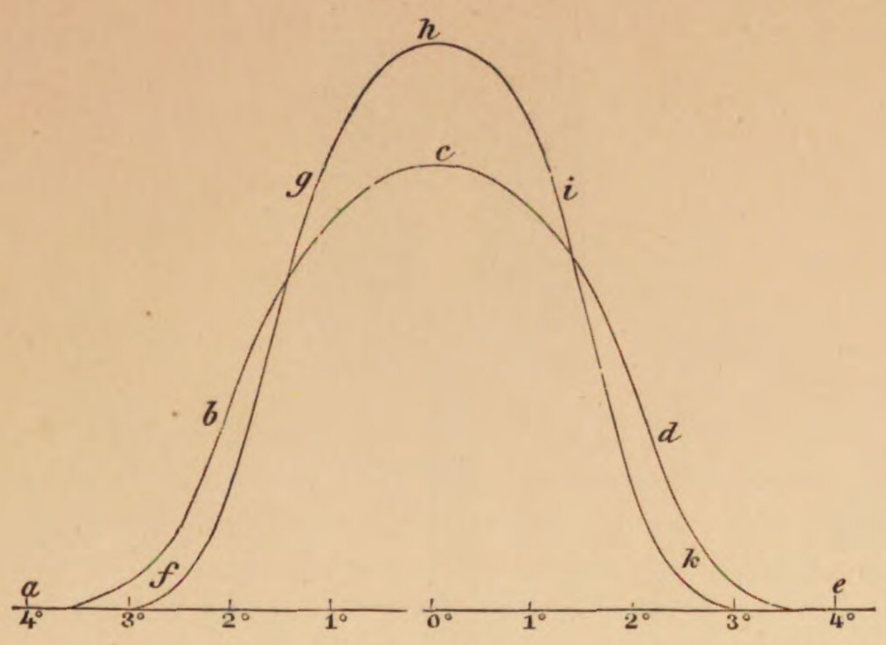

The focus of the drum formed by the dioptric lenses is situated at O in both figures. All the rays emanating from it, as O M and O N, are refracted parallel to that one which, starting from the same point, passes through the axis of the lens; the others diverge more or less, according to the part of the flame from which they emanate; and the extreme limits of the divergence in the horizontal plane are given by the lines A C and B D, which are, respectively, parallel to the two tangents to the flame drawn through the center of the lens. In the vertical plane it may be said that these limits are marked by the lines Q R and S T, which are, respectively, parallel to the two lines passing through the center of the lens, one through the highest, the other through the lowest point of the flame. All the rays which have their point of departure above the focus give a dip to the light; those which have their point of departure below the focus are inclined upward.

When the drum is cylindrical instead of polyhedral the lenses are cylindrical and not annular. The luminous rays are distributed uniformly over the horizon, and their course in a vertical plane through the axis of the apparatus has the same direction as those have from annular lenses.

A section of the luminous beam at right angles to its axis gives an inverted image of the flame beyond the point where the ascending and descending rays cross each other. The angular amplitude of that image, referred to the focus, is inversely proportional to its actual dimensions; it diminishes as the distance increases, and it therefore follows that it is not a matter of indifference, in making photometric measurements, to be stationed at a greater or less distance from the lens whose effects are to be determined. The intensities would be found greater when farther off if the opacity of the atmosphere did not affect the results. Thus, when experiments were carefully made, in 1852, in the cellar of the wine-market at Paris, the intensities, as shown by the photometer, increased up to a distance varying from 80 to 150 meters, but beyond that they diminished, which they would not have done had the atmosphere been perfectly transparent.

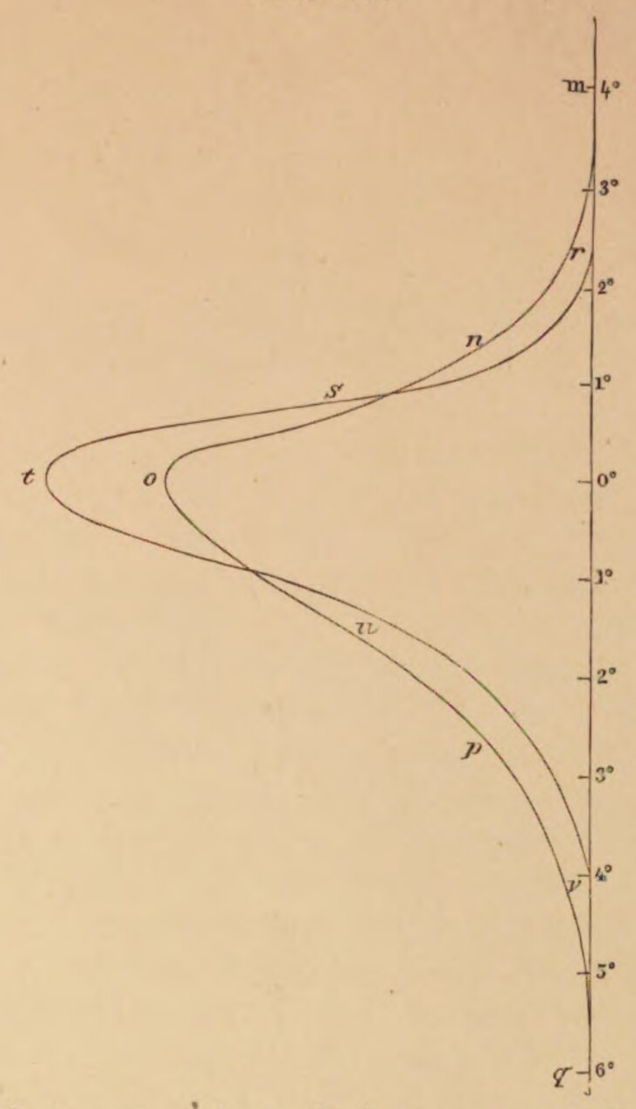
The figures below give some idea of the variation of amplitude, and of brilliancy of the luminous beam emanating from an annular lens of the first order, embracing an eighth of the circumference, according as it is measured at 25 or 100 meters from the focal point.

FIG. 14.




The curves *a b c d e*, and *f g h i k*, of Figure 14, represent the distribution of the luminous rays in the horizontal plane of greatest brilliancy. The degrees are laid off on the axis of abscissæ, and the luminous intensities upon that of ordinates, upon a scale of one centimeter for one thousand burners. The first of these curves is constructed for a distance of 25 meters, and the second for a distance of 100 meters.

FIG. 15.




The curves *m n o p q* and *r s t u v*, of Figure 15, on the same scale, and also constructed for distances of 25 and 100 meters, show how the rays are distributed in the vertical plane through the axis of the lens.

All of these lines have been traced according to the mean results deduced from numerous experiments, leaving slight anomalies out of account.*

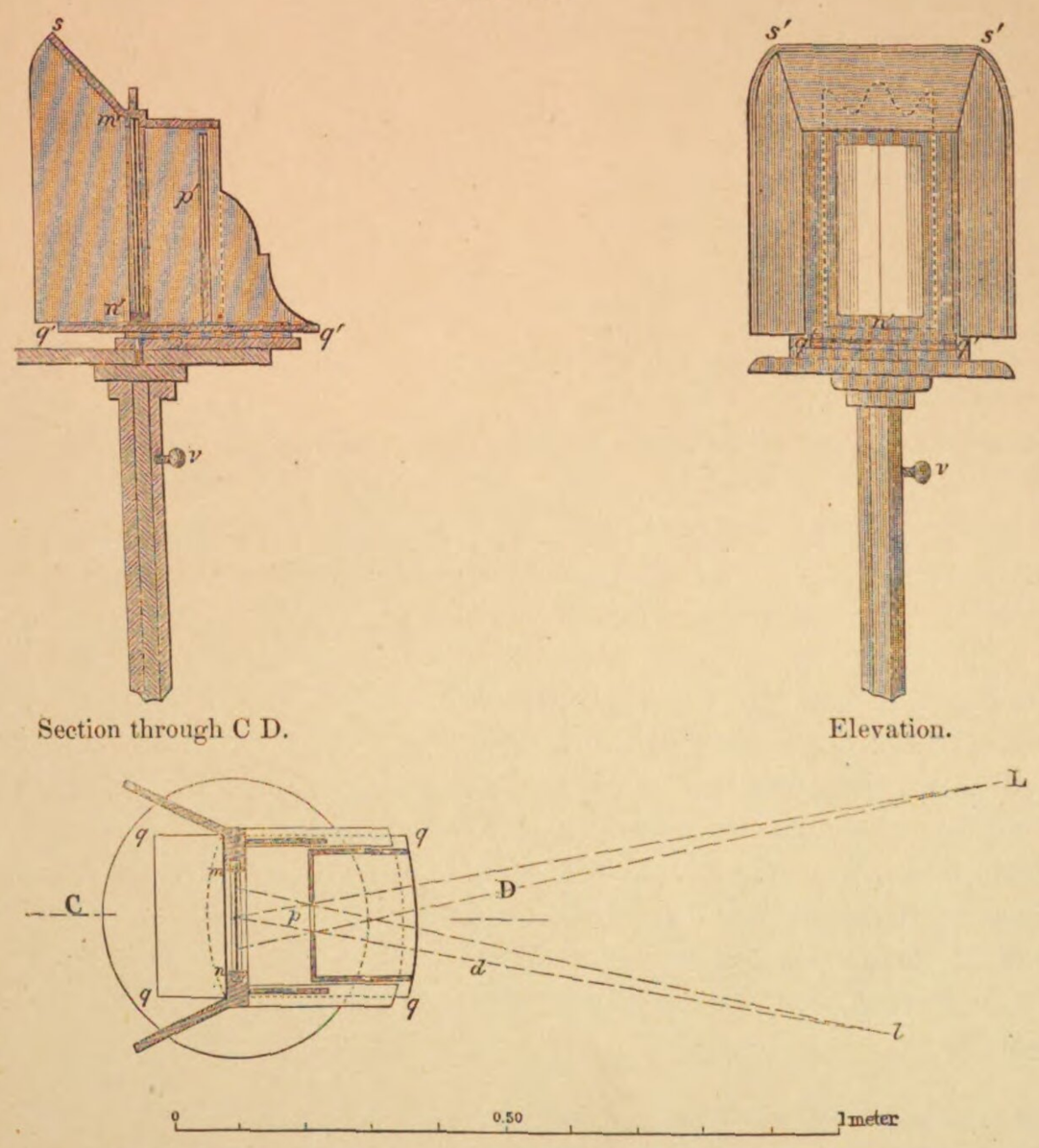
*It seems necessary to show how our photometric experiments were made. The method generally employed consists in comparing the shadows thrown upon a white screen by an object illuminated by the two lights to be compared; one of these lights is moved nearer or farther away until the two shadows appear to be of the same shade, and the comparative luminous intensities are calculated according to the law of the square of the distances. This apparatus has a great merit in the readiness with which it can be improvised at any time, a sheet of paper and a pencil being all that is required; but the results are wanting in precision, for the reason that the observer can with difficulty place himself exactly between the two shadows on a line perpendicular to the screen, and, besides, the brilliantly lighted ground on which the shadows are projected injures, to a certain extent, the delicacy of vision.

The photometer used in the light-service was constructed by Engineer Degrand; instead of comparing the shadows cast, he compared luminous bands thrown on a dark ground. It is represented by the figures below (16) in plan, section, and elevation, and

Beyond a distance of 100 meters the variations of amplitude, and, consequently, of intensity, are but slight, and it was not thought necessary to go beyond for fear that the want of transparency of the atmosphere would too much affect the results. We have therefore used that distance in measuring the intensities of the different apparatus, as given further on.

The results are sensibly the same, except as regards the inclination of the rays as long as the axis of the flame coincides with that of the apparatus and the focus of the lens is situated in the interior of that flame. It may therefore be ascertained from the preceding figure how the flame should be placed with reference to the optical focus, according to the object to be accomplished. If it be required to counteract the dispersion of the luminous rays above the horizontal plane, the lowest point of the flame should be placed at the focus; but if it be desired to throw the light the greatest possible distance in the horizontal plane, the focus should be placed at the most brilliant point—that corresponding to zero of the figure. It will shortly be shown how this point should be placed with reference to the focus, according to the height of the light-house above the level of the sea.

FIG. 16.

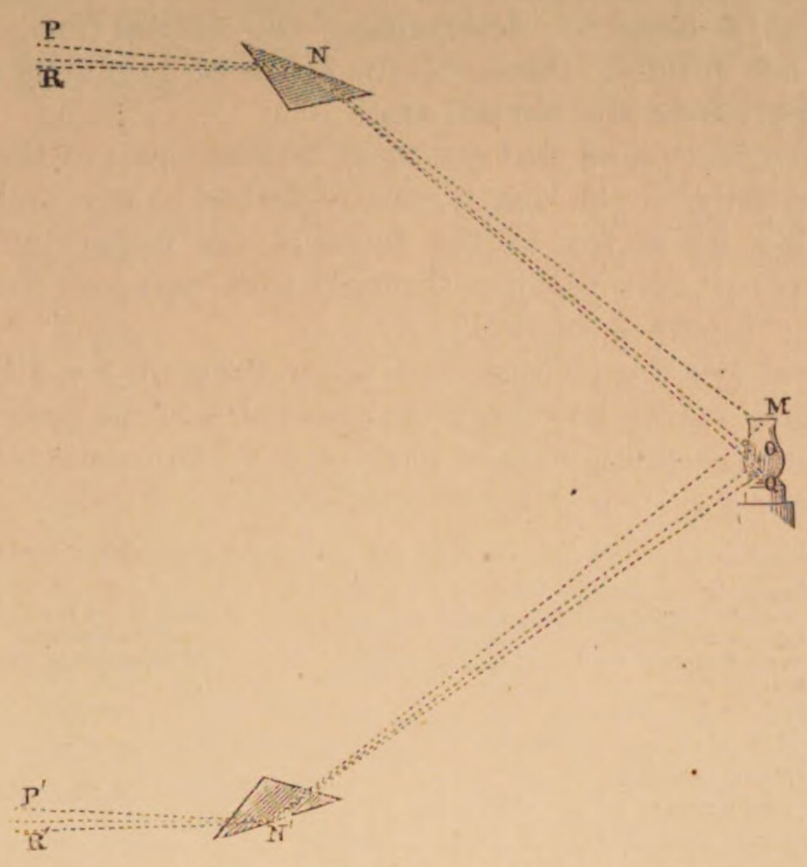



may be described as follows: The rays emanating from each light, L, $l$, are received upon a pane of glass, $m\ n\ m'\ n'$, covered by a sheet of paper or a coat of gum-lac, after having passed through a slit $p\ p'$ made in the axis of a vertical screen interposed between the pane and the lights. The observer places himself on the other side of the pane, from which he can withdraw more or less, to compare the intensities of the two luminous bands which he has before his eyes. The band seen to the right is produced by the light L and the other by the light $l$. He may move backward or forward the screen, which is placed upon a board, $q\ q\ q'\ q'$, sliding between two grooves, and, according as he may find it convenient, place the bands together, or separate them either by a dark band or a more luminous band produced by both lights. It is essential that the rays emanating from the two lights should be equally inclined upon the glass, and to assure this the line of separation of the two bands must coincide with a vertical line dividing the pane into two equal parts. To effect this the photometer is turned upon the plate which supports it. It is equally necessary that the two lights and the center of the glass be in the same horizontal plane, and the instrument may be raised or lowered at will, by means of a support sliding in a socket and held by a thumb-screw, V. Every part of the photometer is painted a dead black, so as to prevent reflections of the luminous rays, and a large black curtain, fixed at its upper part $s\ s'\ s'$, enables the observer to completely isolate himself. The distances to be measured are those from the lights to the center of the glass. Designating them by D and $d$, we have—

$$L = l \frac{D^2}{d^2}.$$

After having been reflected by the catadioptric rings, the rays emanating from those parts of the flame situated above or below the optical focus diverge in a manner just the reverse of those which are transmitted through the dioptric lenses.

FIG. 17.




Those above, as M N P and M N′ P′, (Figure 17,) are directed upward; those below, as Q N R and Q N′ R′, are transmitted below the horizontal plane. Thus the greater part of these rings are calculated for optical foci different from that of the dioptric lens.

For each direction in which the light is seen there is a corresponding thin section of maximum intensity in which we may regard the light as uniformly distributed, and the center of which may be taken for the center of the ring on that side. Doubtless neither the position nor the limits of this brilliant section can be defined with great accuracy, for they depend upon the form and constitution of the flame, which are variable and irregular; but the difference of intensity between two rays proceeding from closely proximate points of the flame is too little to make it of real importance to obtain an exact solution of the problem. The foci of the rings in question have therefore been determined as follows: The flame is placed in the middle of the dioptric drum of the apparatus, so that the center of the horizontal section of greatest brilliancy shall coincide nearly with the optical focus; then the foci to be assigned to the rings are fixed in accordance with considerations which have just been discussed. It was thus decided to adopt a single focus for all the upper catadioptric rings, and, in the lights of the first two orders, to establish it at 0.01 of a meter above that of the dioptric lenses.

The foci of the rings below the lenticular drum were raised still more, because no use could be made of the luminous rays intercepted by the lamp-burner. Their heights above the dioptric focus were made to vary from one ring to another from 0.010 of a meter to 0.035 of a meter for the first order, to 0.032 of a meter for the second, to 0.022 of a meter for the third, and within much closer limits for smaller apparatus. For similar reasons other profiles, of which an account will be given further on, are allowed for apparatus illuminated either by schist oil, petroleum, or an electric current.

The profiles of Plate 3 show very clearly the outlines of our principal apparatus. Figures 1, 2, and 3 relate, respectively, to the first, second, and third orders, and Figures 4, 5, and 6 to apparatus 0.50 of a meter, 0.375 of a meter, and 0.30 of a meter diameter,

illuminated by colza oil; Figure 7 is an apparatus for schist oil; Figures 8, 9, 10, and 11 give the profiles of lenses of vertical elements corresponding to the dioptric drums of the first four.

It has been proved by experiment that each of the different sections of the apparatus thus arranged transmits horizontally, or rather in a direction slightly inclined, the most brilliant part of its beam when the illuminating flame occupies the position and has received the development used as a basis for determining the optical foci. It is easy to see that if these conditions are not fulfilled there will be a loss of luminous rays, which will be the greater the more we depart from the normal state.

Direction to be given to the luminous beams.

It is not in the horizontal plane that the most brilliant part of the luminous beam should be directed; it is tangentially to the sea horizon—that is to say, following the generatrices of a conic surface having its vertex at the focus of the apparatus, and generated by the revolution around a vertical axis passing through that point of the curve determined by atmospheric refraction. (Figure 2, page 28)

The following table shows the inclination of these tangents for different heights above the level of the sea, and it also shows how high the focus should be raised above the axis of the dioptric lens in order that the most intense part of the beam emanating from the lens may follow the desired direction:

| Height of the luminous focus above the surface of the sea, H (in meters.) | Distance of the point of contact of the luminous ray tangent to the surface of the sea. $D = \sqrt{\frac{R\,H}{0.42}}$, R = 6 366 953 (in meters.) | Inclination of the luminous rays which are tangent to the horizon, tang. $a = \frac{0.84\,D}{R}$. | Raising of the focal center, (in millimeters,) for apparatus in which F = | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0.92*m.* | 0.70*m.* | 0.50*m.* | 0.25*m.* | 0.15*m.* |
| | | ′ ″ | | | | | |
| 5 | 8 706 | 3 57 | 1.1 | 0.8 | 0.6 | 0.3 | 0.2 |
| 10 | 12 312 | 5 35 | 1.5 | 1.1 | 0.8 | 0.4 | 0.2 |
| 15 | 15 079 | 6 50 | 1.8 | 1.4 | 1.0 | 0.5 | 0.3 |
| 20 | 17 412 | 7 54 | 2.1 | 1.6 | 1.1 | 0.6 | 0.3 |
| 25 | 19 468 | 8 50 | 2.4 | 1.8 | 1.3 | 0.6 | 0.4 |
| 30 | 21 326 | 9 40 | 2.6 | 2.0 | 1.4 | 0.7 | 0.4 |
| 35 | 23 034 | 10 27 | 2.8 | 2.1 | 1.5 | 0.8 | 0.5 |
| 40 | 24 625 | 11 10 | 3.0 | 2.3 | 1.6 | 0.8 | 0.5 |
| 45 | 26 118 | 11 51 | 3.2 | 2.4 | 1.7 | 0.9 | 0.5 |
| 50 | 27 531 | 12 29 | 3.3 | 2.5 | 1.8 | 0.9 | 0.5 |
| 55 | 28 875 | 13 6 | 3.5 | 2.7 | 1.9 | 1.0 | 0.6 |
| 60 | 30 159 | 13 41 | 3.7 | 2.8 | 2.0 | 1.0 | 0.6 |
| 65 | 31 390 | 14 14 | 3.8 | 2.9 | 2.1 | 1.0 | 0.6 |
| 70 | 32 575 | 14 46 | 4.0 | 3.0 | 2.1 | 1.1 | 0.6 |
| 75 | 33 719 | 15 18 | 4.1 | 3.1 | 2.2 | 1.1 | 0.7 |
| 80 | 34 825 | 15 48 | 4.2 | 3.2 | 2.3 | 1.1 | 0.7 |
| 85 | 35 896 | 16 17 | 4.4 | 3.3 | 2.4 | 1.2 | 0.7 |
| 90 | 36 937 | 16 45 | 4.5 | 3.4 | 2.4 | 1.2 | 0.7 |
| 95 | 37 949 | 17 13 | 4.6 | 3.5 | 2.5 | 1.3 | 0.8 |
| 100 | 38 935 | 17 40 | 4.7 | 3.6 | 2.6 | 1.3 | 0.8 |
| 105 | 39 897 | 18 6 | 4.8 | 3.7 | 2.6 | 1.3 | 0.8 |
| 110 | 40 835 | 18 31 | 5.0 | 3.8 | 2.7 | 1.3 | 0.8 |
| 115 | 41 753 | 18 56 | 5.1 | 3.9 | 2.8 | 1.4 | 0.8 |
| 120 | 42 651 | 19 20 | 5.2 | 3.9 | 2.8 | 1.4 | 0.8 |
| 125 | 43 531 | 19 45 | 5.3 | 4.0 | 2.9 | 1.4 | 0.9 |
| 130 | 44 393 | 20 8 | 5.4 | 4.1 | 2.9 | 1.5 | 0.9 |
| 135 | 45 238 | 20 31 | 5.5 | 4.2 | 3.0 | 1.5 | 0.9 |
| 140 | 46 069 | 20 54 | 5.6 | 4.3 | 3.0 | 1.5 | 0.9 |

| Height of the luminous focus above the surface of the sea, H (in meters.) | Distance of the point of contact of the luminous ray tangent to the surface of the sea, $D=\sqrt{\frac{R\,H}{0.42}}$, R = 6 366 953 (in meters.) | Inclination of the luminous rays which are tangent to the horizon, $\text{tang. } a=\frac{0.84\,D}{R}$. | Raising of the focal center, (in millimeters,) for apparatus in which F = | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0.92*m.* | 0.70*m.* | 0.50*m.* | 0.25*m.* | 0.15*m.* |
| | | ′ ″ | | | | | |
| 145 | 46 884 | 21 16 | 5.7 | 4.3 | 3.1 | 1.5 | 0.9 |
| 150 | 47 686 | 21 38 | 5.8 | 4.4 | 3.1 | 1.6 | 0.9 |
| 155 | 48 474 | 21 59 | 5.9 | 4.5 | 3.2 | 1.6 | 1.0 |
| 160 | 49 249 | 22 20 | 6.0 | 4.5 | 3.2 | 1.6 | 1.0 |
| 165 | 50 013 | 22 41 | 6.1 | 4.6 | 3.3 | 1.6 | 1.0 |
| 170 | 50 765 | 23 1 | 6.2 | 4.7 | 3.3 | 1.7 | 1.0 |
| 175 | 51 506 | 23 22 | 6.3 | 4.8 | 3.4 | 1.7 | 1.0 |
| 180 | 52 237 | 23 41 | 6.3 | 4.8 | 3.4 | 1.7 | 1.0 |
| 185 | 52 957 | 24 1 | 6.4 | 4.9 | 3.5 | 1.7 | 1.0 |
| 190 | 53 668 | 24 20 | 6.5 | 5.0 | 3.5 | 1.8 | 1.1 |
| 195 | 54 370 | 24 40 | 6.6 | 5.0 | 3.6 | 1.8 | 1.1 |
| 200 | 55 063 | 24 58 | 6.7 | 5.1 | 3.6 | 1.8 | 1.1 |
| 205 | 55 747 | 25 17 | 6.8 | 5.1 | 3.7 | 1.8 | 1.1 |
| 210 | 56 422 | 25 35 | 6.8 | 5.2 | 3.7 | 1.9 | 1.1 |
| 215 | 57 090 | 25 54 | 6.9 | 5.3 | 3.8 | 1.9 | 1.1 |
| 220 | 57 750 | 26 12 | 7.0 | 5.3 | 3.8 | 1.9 | 1.1 |
| 225 | 58 403 | 26 29 | 7.1 | 5.4 | 3.9 | 1.9 | 1.2 |
| 230 | 59 048 | 26 47 | 7.2 | 5.5 | 3.9 | 1.9 | 1.2 |
| 235 | 59 686 | 27 4 | 7.2 | 5.5 | 3.9 | 2.0 | 1.2 |
| 240 | 60 318 | 27 21 | 7.3 | 5.6 | 4.0 | 2.0 | 1.2 |
| 245 | 60 943 | 27 38 | 7.4 | 5.6 | 4.0 | 2.0 | 1.2 |
| 250 | 61 562 | 27 55 | 7.5 | 5.7 | 4.1 | 2.0 | 1.2 |
| 255 | 62 174 | 28 12 | 7.5 | 5.7 | 4.1 | 2.1 | 1.2 |
| 260 | 62 781 | 28 28 | 7.6 | 5.8 | 4.1 | 2.1 | 1.2 |
| 265 | 63 382 | 28 45 | 7.7 | 5.9 | 4.2 | 2.1 | 1.3 |
| 270 | 63 977 | 29 1 | 7.8 | 5.9 | 4.2 | 2.1 | 1.3 |
| 275 | 64 567 | 29 17 | 7.8 | 6.0 | 4.3 | 2.1 | 1.3 |
| 280 | 65 151 | 29 33 | 7.9 | 6.0 | 4.3 | 2.1 | 1.3 |
| 285 | 65 730 | 29 49 | 8.0 | 6.1 | 4.3 | 2.2 | 1.3 |
| 290 | 66 304 | 30 4 | 8.0 | 6.1 | 4.4 | 2.2 | 1.3 |
| 295 | 66 873 | 30 20 | 8.1 | 6.2 | 4.4 | 2.2 | 1.3 |
| 300 | 67 438 | 30 35 | 8.2 | 6.2 | 4.4 | 2.2 | 1.3 |

To be perfectly exact, it would be necessary to vary, with the height of the apparatus above the level of the sea: 1st, the position of the lamp with reference to the base of the lenticular drum; 2d, the inclination of the dioptric lenses; 3d, the profiles of the catadioptric rings. But taking into consideration the usual elevation of lights and the dimensions and oscillations of the flame, the two first modifications are necessary only in exceptional cases, and the last is hardly ever required.

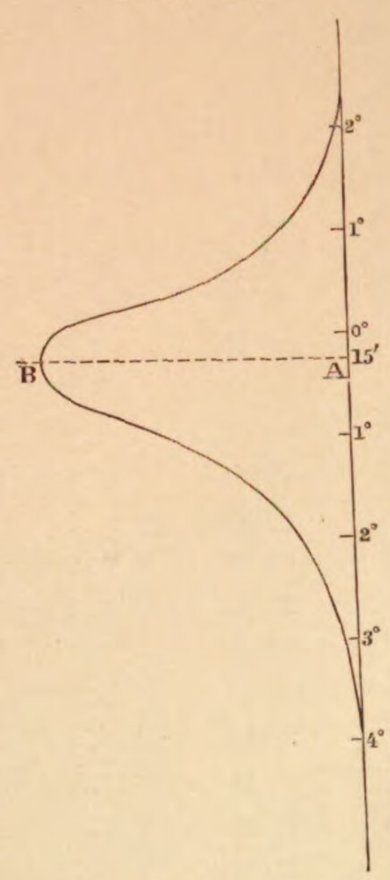
Position of the flame in first-order apparatus.

When the flame of a first-order apparatus is as well developed and as brilliant as it can be made, that is to say, when it is 0.10 of a meter high and appears white over the greater part of its surface, the zone of greatest brilliancy commences at about 0.015 of a meter above the crown of the burner, and extends to about 0.050 of a meter above the same point. The position of the lamp within the apparatus is regulated accordingly. In all the lights of that order which have a height above the level of the sea from 45 to 100 meters, and those are

the most numerous, the burner is set at 0.028 of a meter below the focus of the dioptric lens, which places it 0.038 of a meter below that of the upper catidioptric rings. The luminous beam of the greatest intensity proceeding from the entire apparatus, whatever may be the characteristic of the light, is slightly inclined to the horizon at an angle which varies with the degree of perfection with which the prisms are set and the oscillations of the flame; and more rays are sent below than above the horizon.

It is evident that this angle cannot be determined with great precision; neither the processes of construction nor the practical means of veryifying the apparatus permit it; but it can, however, be said that it is about 15 minutes when the apparatus is made with the accuracy which our able constructers attain. But with the lights in question, the lines inclined may be considered as tangent to the surface of the sea, their deviation being entirely neglected.

FIG. 18.




An example will illustrate this essential point, which has not always been well understood. Figure 18 shows how the luminous rays emanating from an entire apparatus for a fixed light of the first order are distributed in the vertical plane above and below the dioptric focus when the burner is set 0.028 of a meter below that point and the flame fully developed. The angular spaces have been referred to the axis of ordinates on a scale of 0.01 of a meter per degree, and the intensities are expressed on the axis of abscissæ on the scale of 0.01 of a meter per 200 burners. The focus of the apparatus is placed at zero of the axis. The beam of greatest intensity A B makes with the horizon an angle of about 15 minutes. The rays above are projected toward the sky; all those below, and they are the most numerous, strike the surface of the sea when the height of the light is a mean between the limits just referred to.

Form of a luminous beam.

The following figure will give an idea of the subject. It represents the real form of the section made by a vertical plane through the focus of a luminous beam from a first-order fixed-light apparatus, in what may be considered a mean state of the atmosphere, that is to say, when the unit of light has a range of 7 kilometers. The distances are represented on a

FIG. 19.




scale of 0.007 of a meter per nautical mile. The focus is at F, and the line of greatest luminous intensity F O is that which ought to be directed tangentially to the horizon. The part

of the beam above that line is lost to the mariner, and that below alone reaches the surface of the sea.

We thus see how the range will be reduced if it be desired to utilize the whole of the light transmitted by the apparatus, and we also see that the curve is so flat at its vertex that a variation of some minutes in the direction of the line F O will not exert a sensible influence upon the range of the light.

Modifications of the apparatus required because of the height of the focal plane.

When the focal plane of the light-house is more than 100 meters above the level of the sea modifications of two kinds become necessary, viz: those affecting the luminous beam proceeding from the lenticular drum, and those affecting the beams reflected by the catadioptric rings.

As regards the drum, the lamp-burner is raised according to the height of the focal plane, and conformably to the figures of the foregoing table, so as to have the beams properly inclined. But the distance 0.028 of a meter from the crown of the burner to the center of the drum, being established in view of a mean elevation of about 70 meters, ought not to be reduced more than by the difference between the figures of the table and those which correspond to that height, viz, 0.004 of a meter. Thus, for a light 150 meters above the level of the sea, the crown of the burner should be placed at 0.028 of a meter $-(0.0058m.-0.0040m.)=0.0262m.$ below the horizontal plane passing through the center of the drum. A loss of light results from the form of the lenses, but it is practically insignificant.

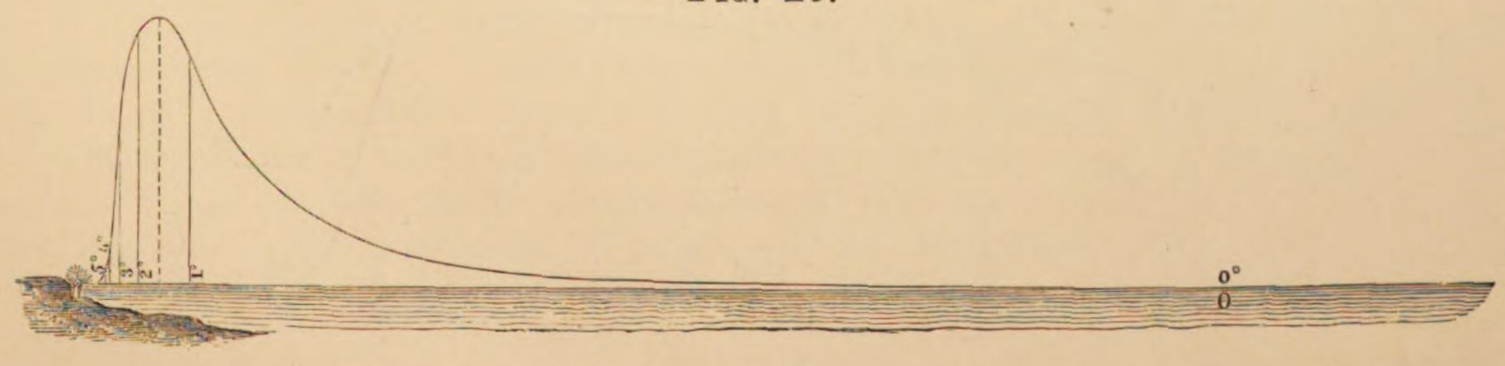
In eclipse lights of very considerable elevation, such as that of Cape Carbon, in Algeria, which is 220 meters above the level of the sea, the lenses of the drum are inclined in such a manner as to render them normal to the line tangent to the horizon, and the burner is placed at 0.028 of a meter + 0.004 of a meter, or 0.032 of a meter below the focus. The drum is of the form of a truncated pyramid. This cannot be done in fixed apparatus, as it would be necessary to give a conical form to the drum, which would occasion difficulties of construction not sufficiently justified in practice. Moreover, great heights above the level of the sea are rarely selected, for the reason that very high points are subject to be enveloped in fog when it is clear below.

In raising the burner, the effect on the catadioptric parts of the apparatus is the reverse of that on the drum; the luminous beam is raised instead of lowered upon the horizon, and it would be necessary to calculate a special profile for each height if it were desired to be perfectly exact. This would be a serious inconvenience; but the problem may be solved more simply and with all the accuracy the subject requires. If the question be in regard to a ring for a fixed light, each of its parts is slightly inclined in such a way that the mean inclination of the reflecting face of each portion sends upon the horizon and below it the most intense beam. If the question be in regard to a catadioptric annular panel like those used for eclipse lights, a movement is given to it analogous to that required for the dioptric panel of the drum. It is easy to understand that approximate solutions are perfectly admissible in such cases, and that extreme precision would be without any actual value, because of modifications constantly occurring in the state of the flame.

Variation of the luminous intensity according to the distance.

It is to be remarked that, although the beam having the greatest intensity is directed to the limit of the horizon, the intensity of light as seen by the navigator increases from this point as the light is approached, then diminishes, and soon after disappears. Figure

FIG. 20.



20 shows the distribution of luminous intensity of a fixed light of the first order, whose focal plane is 60 meters above the level of the sea. The distances are on a scale of 0.007 of a meter per nautical mile upon the axis of the abscissæ, and the quantities of light are carried upon the axis of the ordinates on a scale of 0.10 of a meter per 100 burners. It is seen that in the state of the atmosphere taken as the basis of these calculations, it is about 1.08 miles from the foot of the light-house that the light appears most brilliant. The tangent point of the luminous beam is at O.

Position of the flame in apparatus of the 2d, 3d, and 4th orders.

For similar reasons we direct tangentially to the surface of the sea the most intense part of the luminous beams emanating from apparatus of the other three orders. Taking into account the nature of the flames of these apparatus, the distance to be observed between the focus of the drum and the crown of the burner is regulated as follows for average elevations:

Light of the 2d order: average elevation, 45 meters; distance, 0.026 of a meter.
Light of the 3d order: average elevation, 25 meters; distance, 0.024 of a meter.
Light of the 4th order: average elevation, 12 meters; distance, 0.022 of a meter.

In those of the latter order, which are illuminated with schist oil, the burner occupies another position, as will be shown when we treat of combustibles.

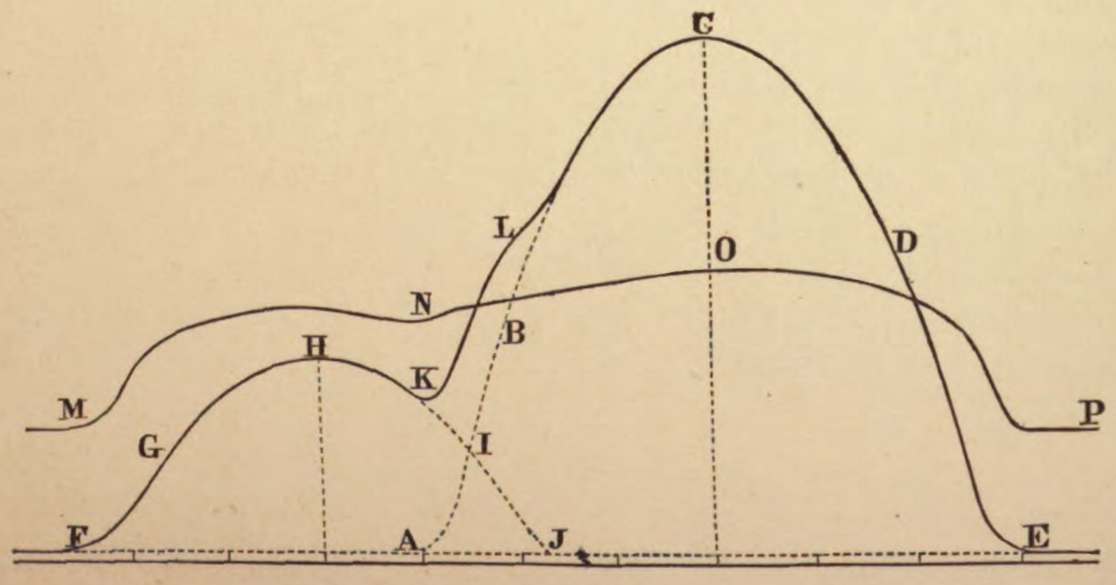
General arrangement of the apparatus.

Apparatus for fixed lights of the first order are composed of eight panels in each of the three parts into which it is divided, and these panels are placed upon the same axis, as shown by Figure 2, Plate 6.

The largest annular lenses of apparatus of the same order only embrace one-eighth of the circumference. They belong to the lights in which eclipses succeed each other every minute. Their divergence being slight, the duration of the flashes is short; from eight seconds when near at hand, it diminishes as the observer recedes. It is longer in the reflector lights, and that merit is highly appreciated by mariners. It would have been easy to remedy the defect which the new system presented, as it would only have been necessary to render the lenses more divergent; but more would have been lost in intensity than would have been gained in duration, and that would have been a very poor solution of the question.

The same result has been obtained by placing the annular catadioptric and the dioptric panels upon different axes. The catadioptric panels deviate slightly, as shown in Figure 4 of Plate 5 and Figure 2 of Plate 7, so that the flashes follow each other instead of being simultaneous. The former make with the latter angles of 4° in horizontal projection, and precede them in the direction of the rotation. The navigator first sees the flash of the catadioptric panel, and then the more powerful flash of the dioptric panel comes into view. The figure below shows the variations of intensity of the total flash; it is shown on a scale of 0.01 of a meter to the degree and 0.001 of a meter to 100 burners.

FIG. 21.



The curve A B C D E is that of the distribution of the luminous rays emanating from the dioptric panel in the plane of greatest intensity, and the curve F G H I J that of the catadioptric panel. The intensities combine where superposed, and the curve F G H K L C D E represents the effect produced by the two united panels. There is one point of inflection, and the height of the first curve being carried down some distance before it comes to the second, it might be feared, on one hand, that the flash would be divided by an eclipse sufficient to deceive mariners as to the true characteristic of the light, and, on the other, that the benefit of the prolongation would be assured on but a small part of the illuminated area; but the curve of ranges corresponding to the intensities in the different directions represented by the line M N O P, which is drawn on a scale of 0.001 of a meter per nautical mile, shows that the evil is not of sufficient importance to be taken into account.

The lower catadioptric rings are not arranged in panels in the lights now under consideration; they are arranged to give a fixed light, as did the parabolic mirrors of the old apparatus.

The same arrangement may be adopted for lights with more frequent eclipses; the velocity of rotation being increased, the intervals between the flashes will be diminished; but the duration of the flashes will be reduced in the same ratio, and it is thought better to increase the number of the lenses, although the intensity of each is thus reduced in about a corresponding degree. The first-order apparatus with eclipses every thirty seconds have, therefore, sixteen panels in the circumference instead of eight. When the flashes succeed each other at shorter intervals, (every twenty seconds and less,) no further effort is made to prolong their duration for fear of too greatly reducing their power, and even the fixed light is suppressed, it being used to augment the intensity of the flashes; the three annular panels are superposed upon the same axis.

Three principal systems are employed to produce what are called *fixed lights varied by flashes*, which are fixed lights presenting at regular intervals white or colored flashes more or less intense. These flashes are sometimes preceded and followed by eclipses of short duration.

The first of these systems consists in causing several lenses of vertical elements to revolve in front of a fixed-light apparatus. These lenses are of the same height as the dioptric drum, and produce in connection with it, an effect analogous to that of an annular lens; they bring together in a beam the luminous rays which, without their interposition, would be uniformly distributed in the angular space which they subtend. An eclipse precedes the flash and another follows it; they are not total, except at great distances from the light, because the movable lenses cover only the drum without affecting the rays from the catadioptric rings.

Figures 5, 8, 12, and 15 of Plate 1 give an idea of the distribution of the luminous rays in apparatus of this sort.

In the second system there are no lenses of vertical elements. Sections of the drum of the fixed-light apparatus are cut out at equal distances and filled in with annular lenses, and the entire drum revolves; sometimes even the whole apparatus revolves when the light is of the lower order. The luminous appearances are the same as in the preceding combination. Preference is given to one or the other arrangement, according as the apparatus is to illuminate the whole or only a part of the horizon. In the latter case lenses of vertical elements take the preference, because they allow that angular space of the fixed apparatus where the luminous rays are not needed to be suppressed, leaving an open space, which facilitates the attendance of the light, and do not require so heavy a weight to move them. But in the first case there is an advantage in employing annular lenses for the reason that there is economy in the expense of establishment, and at the same time economy of light, since the rays which produce the flashes have but one lens to traverse instead of two.

The apparatus of the third system have no eclipses. They are composed of two parts, one over the other; the lower one is arranged after the manner of fixed-light apparatus, the upper like those for eclipses. The latter is put in operation only when the apparatus is not required to illuminate the entire horizon.

Figures 7, 8, and 9 of Plate 5 represent one of these apparatus of the third order.

When it is desired to color the flashes, each of the panels which produce them is covered by a colored pane of glass, and narrow sheets of the same glass are usually added to change the color of the fixed white light during the entire duration of the flash.

The same figures, and those of Plate 10, furnish examples of this arrangement.

Apparatus of the lower orders.

Apparatus of the lower orders are arranged, like those of the first order, according to the effects desired, but they are not generally adapted for as large a number of panels.

Apparatus for electric lights.

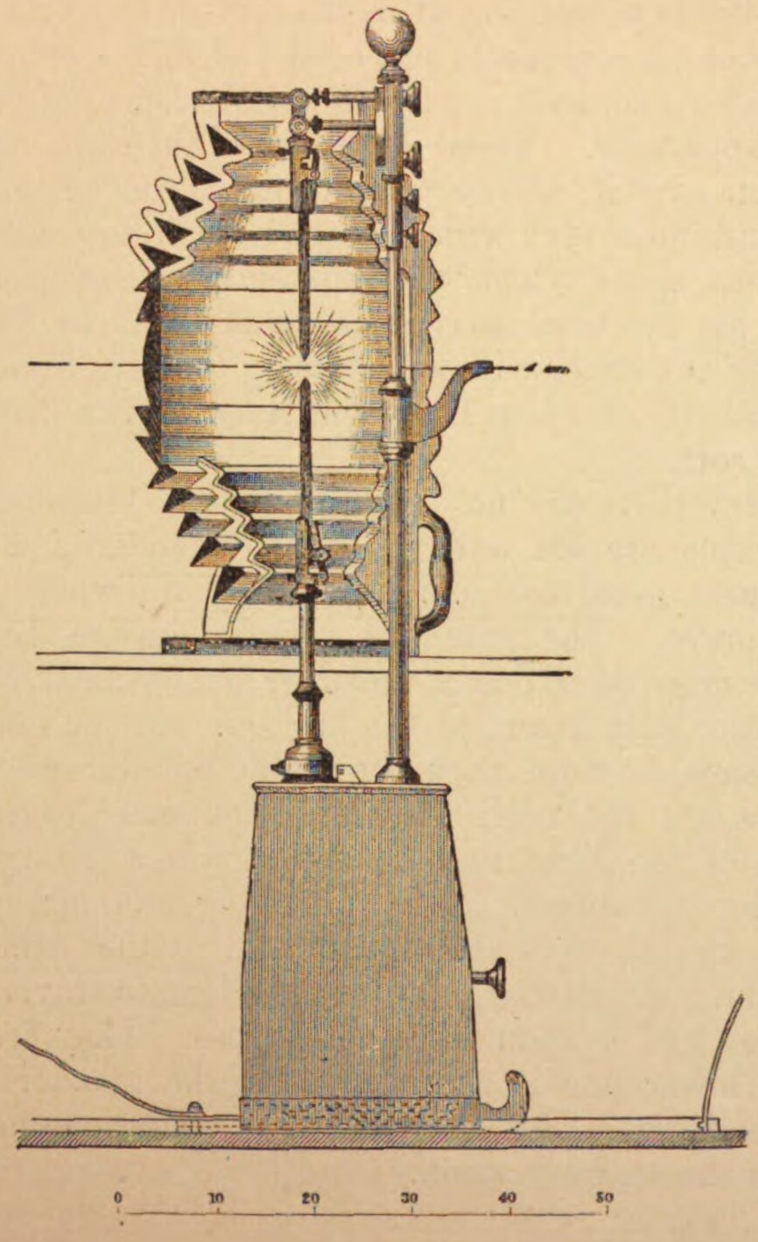
The proper relation to be observed between the dimension of the apparatus and that of the illuminating body at the focus, under penalty of erring by excess or by lack of divergence, unless recourse is had to special profiles, allows the use of apparatus of more contracted dimensions, that is to say, of 0.30 of a meter when the electric light is used. A flame of this kind is not more than 0.01 of a meter wide by 0.012 of a meter to 0.015 of a meter high, and the divergence in the vertical plane of one of these small apparatus is only about 6°—about the same as that of a first-order apparatus, as has been found by experiment.

It has also been thought necessary to dispose the catadioptric rings of the apparatus differently. They have been calculated for the same focus as the lens so as to send the luminous rays not horizontally, but tangentially, to the surface of the sea.

Finally, the small dimensions of the electric flame do not allow the uprights of the frame to be prolonged throughout the entire height of the apparatus, as they would cause the light to be almost totally obscured in their directions; for the same reason, even the joints and indented work of the lenticular profile do not follow horizontal lines as is usual, but the direction taken in the interior of the glass by the rays emanating from the focus after a first refraction.

Figure 22 represents a fixed-light apparatus arranged for the new mode of producing light.

FIG. 22.



Apparatus for schist oil or petroleum.

The form of the flames produced by schist oil or by petroleum also requires special apparatus. Profile 7 of Plate 3 has been established for double-current-of-air lamps like that, the burner and flame of which are represented by Figure 10 of Plate 15. The center of the flame, or rather that of the disk, has been taken for the focus of the dioptric lenses, and the focus of the catadioptric rings has been placed at the same height, but at 0.017 of a meter from the axis, upon the edge of the flame the most distant from the profile for those above, and upon the nearest edge for the first of those below. The focus of the lower ring has been made more eccentric still, and carried to 0.019 of a meter from the axis. It is seen that these arrangements cause the greater part of the luminous rays to be sent in and below the horizontal plane. The shortness of the flame also renders the divergence in the vertical plane notably inferior to that produced by apparatus of the same order illuminated by colza oil; and for the joints of the dioptric profile an arrangement has been adopted analogous to that just referred to in speaking of the electric light.

It will be understood that lenticular apparatus is susceptible of many varied forms, and the engineers should adopt in each particular case those which appear the best adapted to the circumstances of the case. Further on numerous examples will be given.

Luminous intensities of different parts of the apparatus.

The intensities of the luminous beams emitted from the principal parts of the different orders of apparatus may be estimated, in practice, as indicated in the following tables. The first gives the intensities in the axis, and the second the intensities on each side of the axis, for the dioptric annular lenses, the most generally used.

INTENSITIES OF THE LUMINOUS BEAMS ON EACH SIDE OF THE AXIS OF THE APPARATUS.

| Angle, measured from the axis. | Annular dioptric lenses. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st order. | | | 2d order. | | | 3d order. | | | |
| | | | | | | | Large model. | | Small model. | |
| | $\frac{1}{8}$ | $\frac{1}{16}$ | $\frac{1}{24}$ | $\frac{1}{8}$ | $\frac{1}{12}$ | $\frac{1}{20}$ | $\frac{1}{8}$ | $\frac{1}{12}$ | $\frac{1}{6}$ | $\frac{1}{10}$ |
| ° ′ | *Burners.* | *Burners.* | *Burners.* | *Burners.* | *Burners.* | *Burners.* | *Burners.* | *Burners.* | *Burners.* | *Burners.* |
| 0 | 5 015 | 2 465 | 1 600 | 2 525 | 1 650 | 960 | 838 | 543 | 235 | 130 |
| 0.30 | 4 855 | 2 340 | 1 550 | 2 445 | 1 600 | 930 | 805 | 520 | 232 | 128 |
| 1 | 4 375 | 2 150 | 1 395 | 2 205 | 1 440 | 840 | 704 | 456 | 223 | 123 |
| 1.30 | 3 575 | 1 750 | 1 140 | 1 800 | 1 175 | 695 | 538 | 347 | 206 | 114 |
| 2 | 2 450 | 1 210 | 785 | 1 235 | 810 | 470 | 302 | 195 | 184 | 102 |
| 2.30 | 1 010 | 500 | 325 | 525 | 335 | 195 | ..... | ..... | 154 | 85 |
| 2.45 | ..... | ..... | ..... | ..... | ..... | ..... | 0 | 0 | ..... | ..... |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | ..... | ..... | 120 | 67 |
| 4 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 31 | 18 |
| 4.30 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0 | 0 |

INTENSITIES OF THE LUMINOUS BEAMS IN THE AXIS OF THE APPARATUS.

| Kind of apparatus. | Intensity. | | | |
|---|---|---|---|---|
| | Of the lamp only. | Of the upper catadioptric cupola. | Of the central lens. | Of the lower catadioptric cylinder. |
| *Cylindrical lenses for fixed lights.* | *Burners.* | *Burners.* | *Burners.* | *Burners.* |
| 1st order | 23 | 130 | 440 | 60 |
| 2d order | 15 | 70 | 240 | 25 |
| 3d order, large model | 5 | 18 | 65 | 7 |
| 3d order, small model | 3 | 6 | 21.5 | 2.5 |
| 4th order, (0.375*m.*) | 1.6 | 2.7 | 9.3 | 1 |
| 4th order, (0.375*m.*,) for schist oil | 2.2 | 4.5 | 17.5 | 2 |
| 4th order, (0.30*m.*) | 1.3 | 1.8 | 6.4 | 0.8 |
| 4th order, (0.30*m.*,) for schist oil | 2.2 | 3.5 | 13 | 1.5 |
| 4th order, (0.30*m.*,) electric light | 125 | 750 | 2 000 | 750 |
| *Annular lenses for flashing lights.* | | | | |
| 1st order, $\frac{1}{8}$ | 23 | 1 900 | 5 016 | 875 |
| 1st order, $\frac{1}{16}$ | 23 | 950 | 2 465 | 430 |
| 1st order, $\frac{1}{24}$ | 23 | 600 | 1 600 | 275 |
| 2d order, $\frac{1}{8}$ | 15 | 925 | 2 525 | 360 |
| 2d order, $\frac{1}{12}$ | 15 | 600 | 1 650 | 235 |
| 2d order, $\frac{1}{20}$ | 15 | 355 | 960 | 135 |
| 3d order, large model, $\frac{1}{8}$ | 5 | 315 | 838 | 113 |
| 3d order, large model, $\frac{1}{10}$ | 5 | 250 | 665 | 90 |
| 3d order, large model, $\frac{1}{12}$ | 5 | 200 | 543 | 74 |
| 3d order, large model, $\frac{1}{16}$ | 5 | 140 | 400 | 50 |
| 3d order, small model, $\frac{1}{6}$ | 3 | 80 | 235 | 30 |
| 3d order, small model, $\frac{1}{10}$ | 3 | 45 | 130 | 18 |
| *Lenses with vertical elements, for lights varied by flashes.* | | | | |
| 1st order, 7 elements, 34° 12′ | 23 | 1 110 | 3 810 | 530 |
| 2d order, 9 elements, 43° 40′ | 15 | 740 | 2 605 | 300 |
| 3d order, 7 elements, 44° 32′ | 5 | 265 | 925 | 100 |
| 3d order, small model, 5 elements, 50° | 3 | 60 | 230 | 25 |
| 4th order, (0.375*m.*,) 5 elements, 61° 34′ | 1.6 | 34 | 115 | 12 |
| 4th order, (0.375*m.*,) for schist, 5 elements, 61° 34′ | 2.2 | 60 | 215 | 20 |

The figures of these two tables have been obtained by reducing about one-tenth those found in our experiments, to compensate for the imperfections of practice, then by diminishing the results one-tenth more for the absorption of the glass of the lantern.

Mode of constructing lenses.

The glass of Saint Gobain is exclusively used in the construction of our lenses. Its manufacture has been greatly improved within a few years, and leaves but little now to be desired. It is colorless, hard, homogeneous, and absorbs but a small portion of the rays which pass through it; takes a very beautiful polish, resists the action of the atmosphere perfectly,

and contains but a very small number of air-bubbles or of striæ. Its composition is now as follows:

| | |
|---|---|
| Silica - - - - - - - - | 72.1 |
| Soda - - - - - - - - | 12.2 |
| Chalk - - - - - - - - | 15.7 |
| Alumina and oxide of iron, traces - - - | |
| | 100.0 |

Its index of refraction, formerly 1.50, has been raised to 1.54.

The glass is run into iron molds of dimensions somewhat larger than the pieces required, after which the unpolished glass is placed upon turning-lathes worked by steam, where it is turned to the exact forms prescribed and perfectly polished. This operation is long, and requires skilled workmen.

The different parts which enter into the composition of the same lens are worked separately, afterward cemented on their edges by means of mastic, and set in bronze frames. The correctness of the work is determined by the method of conjugate foci. In calculating the lenses care is taken to reduce as far as possible the thickness of the glass so as to diminish the absorption of the luminous rays; but in doing so a certain limit cannot be passed for fear of failing to obtain the required solidity, of rendering the construction too difficult, and above all of incurring too great expense.

These considerations, and the progress made within a short time in the molding of glass, led Engineer Degrand, a few years ago, to think that this last mode of construction might be advantageously applied to the fabrication of echelon lenses, the thickness of which might be considerably reduced. This was a return to the idea of Buffon, but with more incentives and much greater chances of success.

The glass was run into cast-iron molds, turned with the greatest care, particularly the re-entering angles, and small apparatus thus made gave very good results. It has not, unfortunately, been so in others. The economy of luminous rays resulting from the reduction in the thickness of the glass did not compensate for the dispersion due to the irregularities of the surface, and, from all calculations made, it does not appear that the new process is susceptible of extension in the present state of glass manufacture.

The apparatus represented on Plate 10, and by Figures 5, 6, 7, and 8 of Plate 12, were constructed of molded glass.

## III.—COMPARISON OF THE TWO SYSTEMS OF APPARATUS.

The superiority of the dioptric over the catoptric apparatus is due to the following facts:

1st. When light is reflected from the most highly polished metallic surfaces, more luminous rays are absorbed than when it passes through lenses of proper thickness.

2d. When the apparatus are of the dimensions in general use, which dimensions have been adopted after careful study, the divergence of the luminous rays is much greater in catoptric than in dioptric apparatus, and a large part of that divergence cannot be utilized.

3d. Dioptric apparatus allow the distribution of the light uniformly over the entire or only a part of the horizon, which can only be properly done with the catoptric apparatus by a too great multiplication of reflectors, unless those which have received the name of "Sideral Apparatus" are used, in which case, great luminous intensity cannot be produced.

4th. Flashes of much greater intensity are obtained from dioptric apparatus than from the most powerful catoptric apparatus.

The latter class of apparatus usually have the advantage over the former in the expense of first establishment; but this merit is nearly always counterbalanced by a great increase in

annual expense. In other words, the useful effect of the dioptric apparatus is far beyond that of the catoptric, as will be shown by some examples.

Let us take, for comparison, not the quantity of light emanating from the apparatus, but that sent out in the horizontal plane. In fact, this alone is of consequence, as the object we have in view is to direct the rays tangentially to the surface of the sea; *it* determines the range of the light under ordinary conditions of the atmosphere. It is evident that no account can be taken of the rays thrown above the horizontal plane, for they are entirely lost. As for those which descend below, they are no doubt useful to maritime illumination; but it is to be remarked, that in all of our apparatus there are more of these than is strictly necessary, since the apparent intensity of the light increases, as the foot of the tower is approached, throughout the whole extent of the circular area which it is required to illuminate. There is, it is true, some advantage in having, during foggy weather, a great number of rays cast downward, but it is known that under these conditions of the atmosphere an enormous increase of intensity is required to obtain a slight increase of range; thus, the divergence below the horizontal plane becomes ordinarily useless as soon as we pass a certain limit, fully reached in dioptric apparatus, and which there is no real advantage in increasing in foggy weather. It can therefore, be disregarded.

The useful effect of an illuminating apparatus may be deduced from the formula

$$\frac{L}{I+D},$$

in which L represents the quantity of light; I the annual interest on the first cost of apparatus; and D the annual expense of keeping up the light, including the consumption of oil, wicks, chimneys, salaries of keepers keeping the apparatus in order, repairs, &c. The cost of the unit of light sent to the horizon is

$$\frac{I+D}{L}.$$

Apparatus of the fourth order.

If the comparison between the apparatus of the two systems should be made when a new light-house is established, it would then be necessary, in order to be perfectly exact, to include in the value of I the interest on the sum required, or that will be required, for the construction of the edifice.

Let us first compare small apparatus illuminated by the same lamps,—a photophore, a sideral apparatus, and an apparatus made of pressed glass, like that represented by Figure 6, Plate 12, each inclosed in a small movable lantern, and let us allow the last two to illuminate an entire circle. The quantity of light sent to the horizon by the photophore should be represented by the sum of the mean intensities of each degree of illuminated arc, and that of the other apparatus should be expressed by the intensity multiplied by 360.

According to the figures before given, the quantities of luminous rays distributed in the horizontal plane are:

| | Burners. |
|---|---|
| For the photophore, - - - - - - - - - - | 1 005 |
| For the sideral apparatus - - 3.50 burners × 360 = | 1 260 |
| For the lenticular apparatus - - 6.00 " × 360 = | 2 160 |

The cost of the apparatus is as follows:

| | Francs. |
|---|---|
| Photophore - - - - - - - - - - - | 350 |
| Sideral apparatus - - - - - - - - - | 500 |
| Lenticular apparatus - - - - - - - - - | 500 |

From which we obtain for I, the respective values, 17.50 francs, 25.00 francs, and 25.00 francs, allowing five per cent. interest.

The annual expense of maintenance may be estimated as follows:

For the photophore:

| | Francs. |
|---|---|
| Cost of oil, 0.050 kg. × 4 000 + 20 = 220 kg., at 1.51 francs = | 332.20 |
| Salary and fuel for one keeper | 570.00 |
| Wicks, chimneys, and various supplies | 38.00 |
| Care of the apparatus, repairs, &c. | 70.00 |
| Total | 1 010.20 |

For the sideral apparatus:

| | Francs. |
|---|---|
| Cost of oil, 0.045 kg. × 4 000 + 20 = 200 kg., at 1.51 francs = | 302.00 |
| Salary and fuel for one keeper | 570.00 |
| Wicks, chimneys, and various supplies | 40.00 |
| Care of apparatus, repairs, &c. | 80.00 |
| Total | 992.00 |

For the lenticular apparatus:

| | Francs. |
|---|---|
| Cost of oil, 0.050 kg. × 4 000 + 20 = 220 kg., at 1.51 francs = | 332.20 |
| Salary and fuel for one keeper | 570 00 |
| Wicks, chimneys, and various supplies | 42.00 |
| Care of the apparatus, repairs, &c. | 80.00 |
| Total | 1 024.20 |

From which we deduce:

For the photophore: $\frac{L}{I+D} = \frac{1\,005}{17.50 + 1\,010.20} = 0.9779.$

For the sideral apparatus: $\frac{1\,260}{25.00 + 992.00} = 1.2389.$

For the lenticular apparatus: $\frac{2\,160}{25.00 + 1\,024.20} = 2.0587.$

If the cost of the unit of light be represented by 1 with the lenticular apparatus, it will be raised to 1.66 with the sideral apparatus, and 2.11 with a photophore.

Apparatus of the third order.

The quantity of light transmitted to the horizon by a dioptric apparatus of the third order, lighting 360°, and illuminated by a lamp consuming 175 grammes of oil per hour, may be represented by L = 90 burners × 360 = 32 400 burners.

The estimated cost of the apparatus and its lantern is 22 290 francs, as follows:

| | Francs. |
|---|---|
| Lenticular apparatus | 9 100.00 |
| Armature | 1 200.00 |
| Lamps | 1 100.00 |
| Various implements | 540.00 |
| Lantern, including glazing and lightning conductor | 8 350.00 |
| Transportation and placing in position | 2 000.00 |
| Total | 22 290.00 |

From which, calculating the interest at five per cent. and rejecting the cost of the buildings, we obtain I = 1 114.50 francs.

The annual expense of maintenance may be estimated as follows:

| | Francs. |
|---|---|
| Cost of oil, 0.175 kg. $\times$ 4 000 + 90 = 790 kg., at 1.51 francs, | 1 192.90 |
| Salaries and fuel for two keepers | 1 575.00 |
| Wicks, chimneys, and various supplies | 112.00 |
| Care of apparatus, repairs, &c. | 260.00 |
| Total | 3 139.90 |

Useful effect: $\frac{L}{I+D} = \frac{32\,400}{1\,114.50 + 3\,139.90} = 7.62.$

Cost of the unit of light: $\frac{I+D}{L} = 0.131$ francs.

To obtain with a sideral apparatus an intensity equivalent to that of lenticular apparatus, it would be necessary to make it of much greater dimensions than those adopted, and perhaps even greater than could be allowed in practice; but the same effect may be accomplished with reflectors of one nappe, provided there is a sufficient number of them. Twenty-four reflectors of 0.29 of a meter opening, illuminated by lamps consuming 50 grammes of oil per hour, set at equal distances around the circumference of a circle, would give a fixed light whose intensity would be about 67 burners, and the estimated value for the entire horizon would reach, according to the rule just adopted, 24 120 burners.

The cost of this kind of apparatus may be set down at 13 698 francs, as follows:

| | Francs. |
|---|---|
| Twenty-four lamps and reflectors | 1 608 00 |
| Frame, lantern, supplies of various kinds, transportation, and setting up as above | 12 090.00 |
| Total | 13 698.00 |

From which I = 684.90 francs.

Let us suppose that the annual expense of maintenance in this case will not differ materially from the preceding, except in the consumption of oil, wicks, and chimneys. The care of the apparatus will undoubtedly be somewhat more expensive, but let that be disregarded. As there is no such light on our coast, the exact figures for expense of caring for the apparatus are not attainable, and it is not desired to use any in the calculations which are not entirely reliable. The expense, therefore, may be estimated at 10 038.62 francs, as follows:

| | Francs. |
|---|---|
| Cost of oil, 24 $\times$ 0.050 kg. $\times$ 4 000 + 252 kg. = 5 062 kg., at 1.51 francs | 7 643 62 |
| Salaries of two keepers, as above | 1 575.00 |
| Wicks, chimneys, &c. | 560.00 |
| Care of apparatus, &c. | 260.00 |
| Total | 10 038.62 |

Useful effect: $\frac{L}{I+D} = \frac{24\,120}{684.90 + 10\,038.62} = 2.25.$

Cost of the unit of light: $\frac{I+D}{L} = 0.445$ francs.

Relative useful effect of the two apparatus: $\frac{7.62}{2.25} = 3.39.$

If, as is frequently the case, the apparatus is to illumine only three-fourths of the horizon, this difference will not be so great, because no account can be taken of the luminous

rays transmitted to the land-side, and in that case the cost of the light from the catoptric apparatus will be reduced in a greater proportion than the other. We have, therefore, the following figures, which will be understood without recurring to details:

| | Francs. |
|---|---|
| Interest on the cost of the lenticular apparatus - - | I = 1 000.75 |
| Expense of maintenance of the same - - - | D = 3 139.90 |

Useful effect: $\frac{L}{I+D} = \frac{24\,300}{1\,000.75 + 3\,139.90} = 5.87.$

| | Francs. |
|---|---|
| Interest on the cost of catoptric apparatus - - | I = 664.80 |
| Expense of maintenance of the same - - - | D = 7 987.72 |

Useful effect: $\frac{L}{I+D} = \frac{18\,090}{664.80 + 7\,987.72} = 2.09.$

Relative useful effect of the two apparatus: $\frac{5.87}{2.09} = 2.81.$

Apparatus of the two higher orders.

In order to spread around the entire horizon, with a catoptric apparatus, a quantity of light equal to that which would be produced by a lenticular fixed-light apparatus of the second order, it would be necessary to have one hundred reflectors of 0 29 of a meter opening, consuming 50 grammes of oil per hour, or sixty reflectors of 0.50 of a meter opening, consuming 60 grammes per hour. The luminous intensity of the lenticular apparatus being 335 burners, that of the catoptric apparatus reaches 279 burners in the first case, and varies in the second from 350 to 352 burners. The hourly consumption of oil would be, respectively, 500, 5 000, and 3 600 grammes.

Finally, the mounting and attendance of a catoptric apparatus of this description presents such difficulties that none have ever been constructed; it therefore appears unnecessary to push the comparison further.

If the comparison were made with a light of the first order, it would be found that while the lenticular apparatus, consuming 760 grammes of oil per hour, distributes over the entire horizon a light of an intensity equal to 630 carcel burners, sixty reflectors of 0.85 of a meter opening, with a consumption of oil reaching 3 600 grammes, would only give an intensity varying from 550 to 630 burners.

Such an apparatus would be still more objectionable than one of the second order referred to, consequently nothing further need be said of these.

It is proper however, in fairness of comparison to add, that if it be not required to illumine the entire horizon, as has been supposed, but only a small angular space, the inferiority of the catoptric system will not be so apparent. Thus, let us suppose, for instance, that the luminous rays are to be distributed in an angular space of only 45°, it will only require eight reflectors of 0.85 of a meter opening, with lamps of 1.60 burners, to give a light about equal to that of an ordinary lens apparatus of the first order; for, as it has been already stated, *the arrangements employed to collect in the latter apparatus the rays diverging toward the dead angle do not greatly augment the range.* The consumption of oil by the catoptric apparatus will then be reduced to 480 grammes per hour, while with the lenticular apparatus it will be 760 grammes. The expenses of establishment and maintenance would be about the same in each case. Doubtless an arrangement of lenses, better suited for the case in question than that which has been adopted for an angular space greater than 180° could be devised; but the inconveniences that would be developed in practice in introducing a new type of apparatus for each exceptional case which presents itself is readily imagined. The proper conclusion to be drawn from what has been said above, is in strict conformity to what was said when considering catoptric apparatus—that for illuminating small angular spaces they are very desirable.

When we consider lights of the two larger orders, required to illumine not less than one-half of the horizon, the comparison between the two systems can only be made with

eclipse apparatus. We limit ourselves to a single example, so as to avoid tiring the reader with details, and it will suffice to put the question beyond all doubt.

LENTICULAR APPARATUS.

Estimate of cost of light for apparatus of first order with eclipses every minute.

First establishment:

| | Francs. |
|---|---|
| Apparatus, including the frame | 37 940.00 |
| Three mechanical lamps | 2 100.00 |
| Revolving machinery | 3 200.00 |
| Fixtures of various kinds | 900.00 |
| Lantern, including glazing and lightning conductor | 20 400.00 |
| Transportation and setting up of apparatus | 3 900.00 |
| Total | 68 440.00 |

From which, following the notation before adopted, I = 3 422 francs.

Annual maintenance:

| | Francs. |
|---|---|
| Oil, 3 205 kilogrammes, at 1.51 francs | 4 839.55 |
| Salaries and fuel for three keepers | 2 525.00 |
| Wicks, chimneys, and supplies of various kinds | 219.00 |
| Care of apparatus, repairs, &c. | 390.00 |
| Total | 7 973.55 |

The quantity of light sent to the horizon may be represented by 630 burners $\times$ 360 = 226 800 burners, and this is the same whether the apparatus be revolving or fixed.

The catoptric apparatus to be compared with the lenticular one may be composed of twenty-four 0.85 of a meter reflectors, each illuminated by a double-wick lamp consuming 175 grammes of oil per hour, and divided into four groups, six in each. The maximum of the flash will reach 4 560 burners, while it will be 5 075 with the lenses. In order to give the same interval between the flashes the velocity of rotation must be doubled.

The expenses may be estimated as follows:

| | Francs. |
|---|---|
| 24 reflectors fitted with their lamps, at 865 francs | 20 760.00 |
| Armature | 6 300.00 |
| Revolving machinery | 3 200.00 |
| Three spare reflectors | 2 595.00 |
| Lantern, fixtures of various kinds, transportation and setting up as above | 25 200.00 |
| Total | 58 055.00 |

Annual maintenance:

| | Francs. |
|---|---|
| Oil, 0.175 kg. $\times$ 24 $\times$ 4 000 + 550 kg. = 17 350 kg., at 1.51 frs. | 26 198.50 |
| Salaries and fuel for three keepers | 2 525.00 |
| Wicks, chimneys, and supplies of various kinds | 2 688.00 |
| Repairs, &c., the same figures as above, although too small here | 390.00 |
| Total | 31 801.50 |

From which I = 2 902.75 francs, and D = 31 801.50 francs.

The quantity of light transmitted to the horizon by one of these reflectors is estimated at 7 429 burners, which is obtained by adding together the mean luminous intensities of each of the degrees illuminated. That of the entire apparatus will be L = 178 296 burners.

We shall then have for the lenticular apparatus:

Useful effect: $\frac{L}{I+D} = \frac{226\,800}{3\,422 + 7\,973.55} = 19.90.$

Cost of the unit of light: $\frac{I+D}{L} = 0.050$ francs.

And for the catoptric apparatus:

Useful effect: $\frac{L}{I+D} = \frac{178\,296}{2\,902.75 + 31\,801.50} = 5.14.$

Cost of the unit of light: $\frac{I+D}{L} = 0.195$ francs.

The economical value of the lenticular apparatus is therefore nearly four times that of the other, and its relative value is greater as the power of the apparatus is increased.

It is also to be remarked that it would be very difficult for one man to take care of twenty-four (24) double-wick lamps. Such an apparatus has never been made.

The most powerful catoptric eclipse-light apparatus ever used in France had only four 0 85 of a meter reflectors in a group, each with a single-wick lamp. The intensity of its flashes did not exceed 2 700 burners, and consequently was not to be compared with the lenticular apparatus of the two higher orders. At the light-house of Ailly, near Dieppe, there were twelve (12) reflectors arranged in groups of threes, and the maximum intensity of the flashes was 1 650 burners, which is little better than that of a complete annular panel of the third order, embracing one-eighth of the circumference, which gives an intensity of 1 266 burners in the axis.

It is unnecessary to say more to illustrate the merits of the new system. It is proper, however, to add, what has already been said in regard to the superiority of the lenticular apparatus over the reflectors, that, light for light, the care of the lenses is much less laborious for the keepers and more certain to be properly done.

## IV. COLORED LIGHTS.

In describing the different characteristic distinctions given to lights on the coasts of France, we stated that after considerable hesitation the Commission of Lights allowed some of them to be distinguished by color, after careful experiments had established the fact that color did not have the effect upon the ranges which had previously been supposed.

Some observations made upon red lights had put the engineers of the light-house service on the right track. One of them was often surprised at the brilliancy of these lights at long distances, and questioned whether the effect produced on the retina by a red light would not diminish in a less degree as the distance increases, than that produced by a white light.*

It is known that in clothing, tapestry, and glass, it is almost always the red color which strikes the eye most vividly, and it is known, also, that blue and green, the complements of orange and red, afford to weak eyes a kind of relief, while red produces upon them an impression almost painful, and even of such a nature as to injure that organ if prolonged for too long a time.

The first thing to be done in the experiments for solving, if not exactly, at least approximately, the problem presented, was to compare the power of lights of different colors, and to see if they are of the same intensity, or rather if they are equivalent in regard to visibility. Now, by placing before a photometer, arranged as already described, two lights, one red the other white, and observing the two illuminated bands upon the screen, we see that according as one of the lights is moved nearer or farther from the instrument the corresponding band appears more or less brilliant than the other; or, in other words, is more or less plainly visible. Whatever the difference of color may be, this sensation of inequality between the two bands may be shown with great distinctness by moving one of the lights.

*A memoir by Engineer Degraud and myself on this subject was presented, in 1858, to the Academy of Sciences.

It will be seen, then, that by making experiments of this sort we can bring the limits (beyond which there is certainly inequality) closer together, and determine, approximately at least, the photometric distances corresponding to equality. The results reported by a single observer differ so little that a certain scientific value might be given to the means deduced from a great number of measurements; but as the visual organs of all persons are not affected in the same way by color, their estimates may not be the same, as we will soon see.

This granted, photometric experiments, although necessarily made at short distances, show that the law which obtains as to the decrease of visibility of colored lights is not that of the square of the distances which applies to white light. *In the case of red, for example, if the observer placed near the photometer makes the two bands of equal intensity by properly separating the lights, and then moves farther off, the red band will appear more brilliant than the white, and the difference will be more marked as he gets farther from the instrument.* If he wishes to maintain the equality he must bring the white light nearer in proportion as he moves back from the photometer The reverse is the case when the colored light is green or blue; the comparative value of the colored light in this case diminishes as the distance increases. Numerous experiments have established these phenomena beyond doubt; some of them will be cited.

It is known that a light can be colored by placing between the light and the observer a pane of colored glass, or by surrounding the flame with a colored chimney. Both arrangements are made use of in our light-houses, but only the first was used in the experiments referred to. The red color is produced by the salts of copper, silver, or gold, and the shades which correspond to them, are respectively, dark-red with a purple tint, orange-red more or less intense, and ruby. The first of these colors is the most decided, and appears to absorb the most luminous rays when observed at short distances; the last possesses the opposite properties. The various shades, especially those of the red of copper and the red of silver, vary considerably. Observations have been made by many persons who were successively placed at different distances from the photometer. The light taken for unity was, as usual, that of a carcel lamp consuming 40 grammes of oil per hour; but the colored panes were placed before lights of greater intensity, so as to have the colors sufficiently bright upon the photometer. The intensities of the flames of the latter were also determined with great exactness by observations made before the colored glasses were interposed. The panes were placed at 0.30 of a meter in front of the flames, and the photometer was 5 meters distant.

The following table shows the result of the experiments; the luminous intensities are expressed in terms of the same light not colored:

| Number of the experiment. | Color. | Intensity of the flame. | No. of observers. | Value of the colored light observed at a distance from photometer of— | | | | | Mean value. $\lambda$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.20*m.* | 2*m.* | 4*m.* | 6*m.* | 8*m.* | 0.20*m.* | 2*m.* | 4*m.* | 6*m.* | 8*m.* |
| | | *Burn's.* | | | | | | | | | | | |
| 1 | Red of gold | 23 | 1 | 0.272 | 0.396 | 0.472 | 0.518 | 0.571 | 0.262 | 0.382 | 0.482 | 0.555 | 0.614 |
| | | | 2 | 0.229 | 0.345 | 0.402 | 0.460 | 0.500 | | | | | |
| | | | 3 | 0.249 | 0.404 | 0.591 | 0.649 | 0.790 | | | | | |
| | | | 4 | 0.298 | 0.384 | 0.462 | 0.592 | 0.596 | | | | | |
| 2 | Red of silver, ordinary | 21 | 1 | 0.124 | 0.174 | 0.270 | 0.350 | 0.439 | 0.191 | 0.250 | 0.325 | 0.404 | 0.413 |
| | | | 2 | 0.232 | 0.304 | 0.352 | 0.382 | 0.385 | | | | | |
| | | | 3 | 0.187 | 0.251 | 0.336 | 0.472* | 0.451* | | | | | |
| | | | 4 | 0.219 | 0.271 | 0.341 | 0.411* | 0.376* | | | | | |
| 3 | Red of silver, very deep | 22 | 1 | 0.080 | 0.133 | 0.192 | 0.219 | 0.238 | 0.087 | 0.127 | 0.194 | 0.241 | 0.262 |
| | | | 2 | 0.094 | 0.096 | 0.187 | 0.207 | 0.249 | | | | | |
| | | | 3 | 0.094 | 0.163 | 0.227 | 0.347 | 0.362 | | | | | |
| | | | 4 | 0.082 | 0.116 | 0.169 | 0.190 | 0.200 | | | | | |
| 4 | Red of copper, ordinary | 23 | 1 | 0.055 | 0.077 | 0.088 | 0.104 | 0.129 | 0.049 | 0.074 | 0.093 | 0.119 | 0.149 |
| | | | 2 | 0.044 | 0.063 | 0.083 | 0.133 | 0.191 | | | | | |
| | | | 3 | 0.052 | 0.086 | 0.114 | 0.148 | 0.183 | | | | | |
| | | | 4 | 0.044 | 0.071 | 0.086 | 0.089 | 0.093 | | | | | |
| 5 | Red of copper, very deep | 5.4 | 1 | 0.015 | 0.034 | 0.056 | 0.069 | 0.115 | 0.019 | 0.044 | 0.068 | 0.098 | 0.131 |
| | | | 2 | 0.015 | 0.051 | 0.075 | 0.107 | 0.144 | | | | | |
| | | | 3 | 0.022 | 0.048 | 0.070 | 0.102 | 0.118 | | | | | |
| | | | 4 | 0.024 | 0.042 | 0.071 | 0.115 | 0.147 | | | | | |
| 6 | Green, ordinary | 22 | 1 | 0.057 | 0.048 | 0.043 | 0.037 | ..... | 0.073 | 0.062 | 0.056 | 0.048 | ..... |
| | | | 2 | 0.071 | 0.053 | 0.048 | 0.041 | ..... | | | | | |
| | | | 3 | 0.080 | 0.076 | 0.064 | 0.062 | ..... | | | | | |
| | | | 4 | 0.084 | 0.072 | 0.070 | 0.053 | ..... | | | | | |
| 7 | Green, deeper | 4.5 | 1 | 0.040 | 0.034 | 0.030 | 0.028 | ..... | 0.049 | 0.038 | 0.033 | 0.030 | ..... |
| | | | 2 | 0.054 | 0.041 | 0.035 | 0.033 | ..... | | | | | |
| | | | 3 | 0.054 | 0.039 | 0.033 | 0.030 | ..... | | | | | |
| 8 | Blue | 14 | 1 | 0.015 | 0.012 | ..... | ..... | ..... | 0.015 | 0.012 | ..... | ..... | ..... |
| | | | 2 | 0.015 | 0.011 | ..... | ..... | ..... | | | | | |
| | | | 3 | 0.015 | 0.012 | ..... | ..... | ..... | | | | | |
| | | | 4 | 0.013 | 0.012 | ..... | ..... | ..... | | | | | |

The figures marked with an asterisk show anomalies, and indicate an accidental and sudden modification in the brilliancy of the flame.

The observations upon green and blue were not made beyond six meters for the first and two meters for the second, because the colored belts were not sufficiently distinct beyond those distances.

It may appear that the number of experiments were unnecessarily great, but they relate to phenomena which had never before been described, and which are of great importance to maritime illumination. It was thought necessary to show what degree of confidence the observations are entitled to, and to make known the fact that while they vary considerably they still point to the same general conclusion.

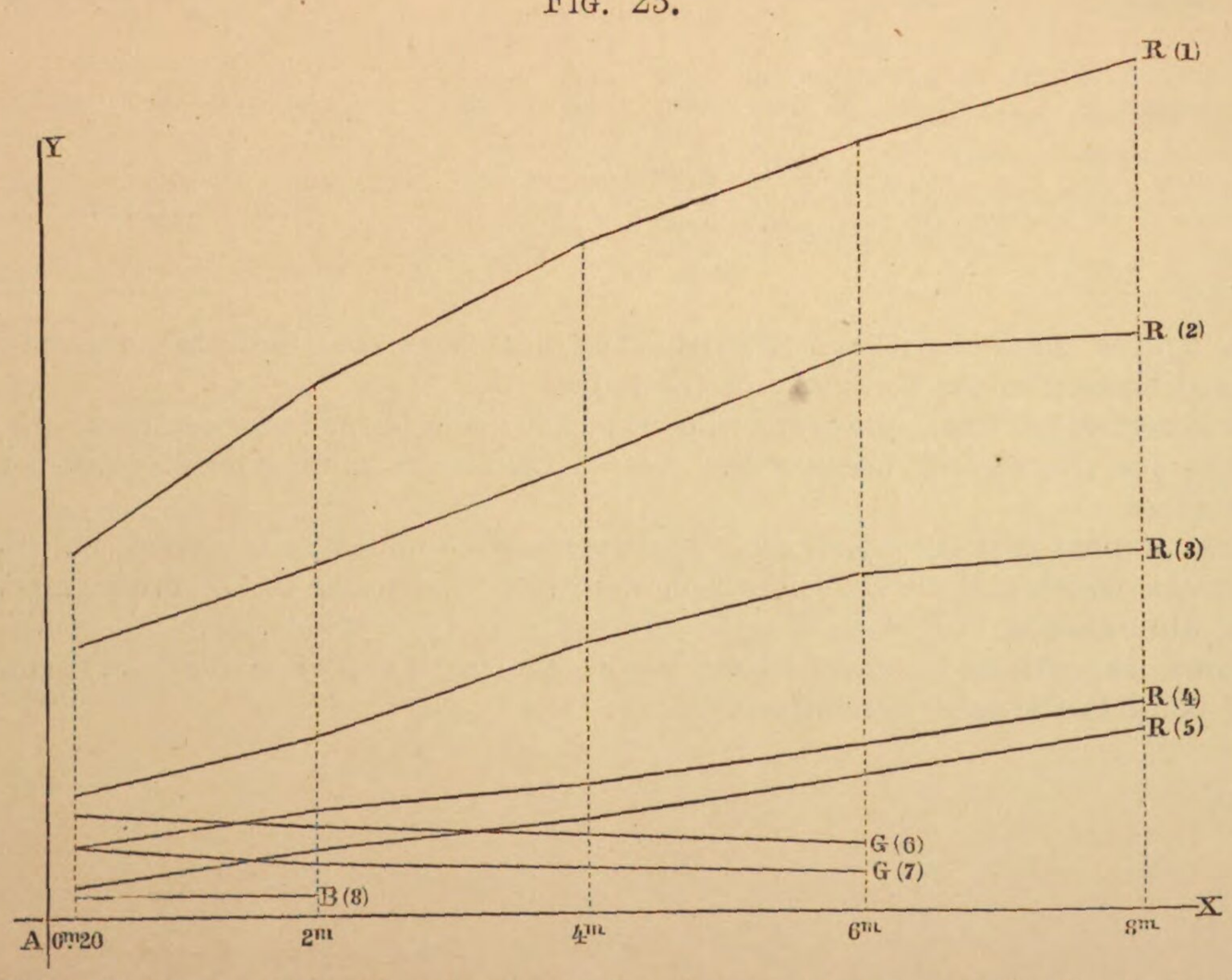
According to the mean values of the preceding table, the comparative intensities of the different colored lights, for the observations made at the different distances from the photometer, varied as follows:

| Color. | | Ratio of intensities. | | |
|---|---|---|---|---|
| | | From 0.20*m*. to 2 meters. | From 0.20*m*. to 6 meters. | From 0.20*m*. to 8 meters. |
| Red | Of gold | $\frac{383}{262} = 1.46$ | $\frac{555}{262} = 2.12$ | $\frac{614}{262} = 2.34$ |
| | Of silver, ordinary | $\frac{250}{191} = 1.31$ | $\frac{404}{191} = 2.11$ | $\frac{413}{191} = 2.16$ |
| | Of silver, very deep color | $\frac{127}{87} = 1.46$ | $\frac{241}{87} = 2.77$ | $\frac{262}{87} = 3.01$ |
| | Of copper, ordinary | $\frac{74}{49} = 1.51$ | $\frac{119}{49} = 2.43$ | $\frac{149}{49} = 3.04$ |
| | Of copper, very deep color | $\frac{44}{19} = 2.32$ | $\frac{98}{19} = 5.16$ | $\frac{131}{19} = 6.89$ |
| Green | Ordinary | $\frac{62}{73} = 0.85$ | $\frac{48}{73} = 0.68$ | ..... |
| | Deeper color | $\frac{38}{49} = 0.77$ | $\frac{30}{49} = 0.61$ | ..... |
| Blue | | $\frac{12}{15} = 0.80$ | ..... | ..... |

It will be remarked that with the red lights the most of the ratios are greater as the color is more intense, and that the red of copper, which absorbs most of the light at short distances gains most as the distance is increased. Experiments made with more powerful apparatus at a distance of several kilometers have even shown, as will soon be seen, that it is visible at a greater distance than the red of silver.

Figure 23 represents, in a more striking manner perhaps than is shown by numbers, the results exhibited in the last column of the first of these tables. It has been constructed by

FIG. 23.




laying off the distances of the observer from the photometer upon the axis of abscissæ on a scale of $\frac{1}{66}$, (nearly,) and the luminous intensities on the axis of ordinates on a scale of 0.15 of a meter per unit of uncolored light.

Line 1 is that of the red of gold; lines 2 and 3 are those of the red of silver; lines 4 and 5 are those of the red of copper; and lines 6 and 7 relate to green. The blue having been observed but twice, is represented by a straight line 8.

In all the experiments the influence which might be occasioned by accidental colors was guarded against as far as possible, and care was always taken to so manage the photometer that the white band would be separated from the colored one by a black band of sufficient width to prevent error from that source. A green tint would have been given to white placed beside red, or a red tint when placed beside green. The black band ought to produce, it is true, a contrast; but the white is not less affected by it than the colored bands, besides, the effect was independent of the position of the observer.

Other experiments made at greater distances seem to have greater value in a practical point of view.

In the first, five flames were regulated in such a way that, four of them being covered with glass colored red of copper, silver, or gold, they all appeared of the same photometric intensity observed at 0.80 of a meter distance. That intensity had been fixed at 0.005 of the carcel burner, so that the limits of the ranges could be reached without going outside of the inclosure of the Champ de Mars, within which the experiments were made. The sky was clear, the night dark, and the observers, four in number, reported as follows:

1. *At a distance of about* 500 *meters the white light ceased to be visible, while the red lights, except the red of gold, were still quite bright.*

2. At 750 meters the same lights remained visible, but the red color was distinct only in the light which was covered by a glass colored very strongly with copper, its absorption being estimated at $\frac{99}{100}$ of the white light.

Another series of experiments was made with more powerful lights and parabolic reflectors of 0.29 of a meter opening, illuminated by lamps of an intensity equal to 1.3 carcel burners, giving in their axes intensities estimated at 60 burners for white light. Before two of them red panes of glass colored by copper but of different shades were placed, and before another a red pane colored by silver. Two white reflector lights were reduced in intensity by uncolored panes of glass, or by coloring with whiting, so that they appeared of the same intensity at a short distance as the colored lights. The lights were too intense for the limits of their range to be reached. The observations were not carried beyond 3 300 meters; but it was always found that the intensity of the red lights diminished much less rapidly than the white as the distance increased.

At 800 meters the five lights appeared of about the same intensity; at 1 400 meters there was a very appreciable difference in favor of the red lights; at 3 300 meters the latter, and especially those colored by copper, surpassed the others.

Two similar reflector lights, one colored by copper-red glass, the other uncolored, were observed at the same distance, 3 300 meters. The ratio of their intensities, measured at a short distance, was $\frac{1}{1.20}$, and yet the first appeared more brilliant than the second.

Analogous experiments made with green and blue lights gave results diametrically opposite to the preceding.

All colored lights lose their character when the limit of their range is approached, and end with being no longer distinguishable; but this effect is much more marked with the green and blue than the red, and with the red of gold than with the others, especially the red of copper.

It is essential to add that all the experiments were made in a clear atmosphere, so that the property possessed by some fogs of making lights appear red had no perceptible effect upon the phenomena. The white lights remained white to the limits of their ranges.

During the fogs referred to, red lights are much superior to the others, because the red rays are much less obstructed in their passage through them; the red rays of white lights pass through such fogs while the others are rapidly absorbed, and green lights after becoming white rapidly diminish in intensity. On this subject the following experiment may be cited:

Five reflectors producing white lights of about 60 carcel burners in the axis were observed during fog. The light of the first was uncolored, that of the second colored red by gold, that of the third colored red by copper, that of the fourth green, and that of the last blue. The white and red lights ceased to be visible at a distance of 1 600 meters. The color of the red of gold was with difficulty distinguishable at 1 500 meters, while that of the red light colored by copper was still well defined. The green light disappeared at 1 000, and the blue light at 530 meters.

Finally, observations made at long distances upon the colored lights of light-houses lead to the same conclusions, and we may call attention to what has already been said in regard to the light at Pontaillac.

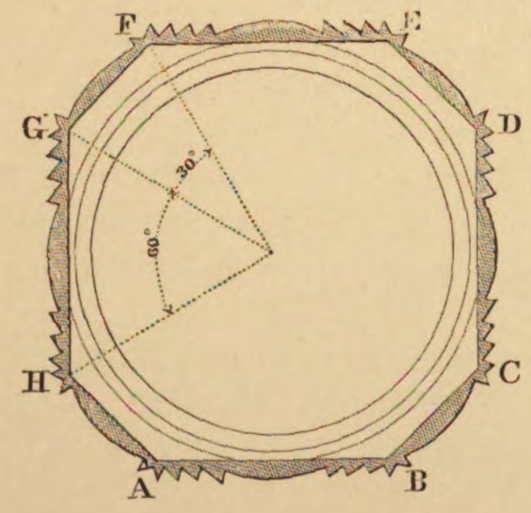
It has been admitted, consequently, in the light-house service, that a red color of a proper shade, produced by a pane of glass colored with copper, will not reduce the intensity of the white light more than from one-half to two-thirds, or, in other words, that to obtain a red and white light of the same range in the ordinary state of the atmosphere, it will suffice to make the white light before being colored from two to three times the intensity of the other. This rule is certainly not very exact; but it may be said that the subject does not admit of the application of exact rules.

It is upon this basis that apparatus are established in which the red and white flashes alternate.

Thus, the first-order apparatus, represented by Figures 5 and 6 of Plate 5, produces a light (flashing) with eclipses every twenty seconds, in which a red flash alternates with a white one, and its cupola of catadioptric prisms has been so arranged that all the luminous rays sent through it are added to those which proceed from the colored panels of the drum and lower rings.

The apparatus of the third order, Figures 7, 8, and 9 of the same plate, shows a fixed white light produced by the greater part of the dioptric drum, as well as by the catadioptric rings below; this light is varied every twenty seconds by flashes alternately red and green, produced by annular panels, dioptric in the lower part and catadioptric above. The fixed white light is equivalent to 60 burners, and each of the panels, give in the axis a flash of 420 burners, reduced to about 150 burners at 2° on either side. The colored flashes are seen somewhat farther than the white light, the green ones at a less distance than the red, especially during foggy weather.

FIG. 24.



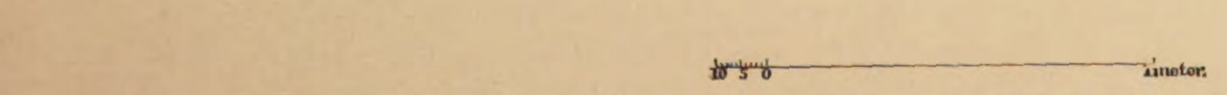




Figure 24 represents the plan of an apparatus also of the third order, the general arrangement of which is like the preceding, but which is designed for a fixed light varied every half minute by flashes alternately red and white, without intervening eclipses. The large sides A B, C D, E F, and G H of the polygon, which forms the base of the movable part,

belong to the panels which are to produce the red flashes; the angular spaces which they embrace are double those which correspond to the white panels. When there is no fog, the range of the white flashes is a little greater than the others.

In fixed lights, the flame is inclosed in a colored chimney. In the eclipse apparatus, sheets of colored glass are placed on either side of and close to the lenses which are to produce the colored flashes. They are held in place by means of bronze frames, which can be moved so as to enable the glass and the lenses to be cleaned

Manner of coloring.

## V. TYPES OF APPARATUS.

Illuminating apparatus are formed in various ways, according to the conditions they are required to fulfill. We shall limit ourselves here to giving the principal types of apparatus in most common use upon the coasts of France, or which seem of most interest.

### 1. FIRST-ORDER APPARATUS FOR A FIXED LIGHT.

Figures 1 and 2 of Plate 5 represent the plan and elevation of such an apparatus;* its section is shown by the right-hand side of Figure 1 of Plate 6. Figure 2 of the same plate shows the elevation of one of its panels, which embraces an eighth of the circumference, and comprises eighteen catadioptric rings above and eight below the dioptric drum The fourth part of the horizontal section of the apparatus occupies the angle C of Figure 1, Plate 4. The plan of the lamp is represented at *d* upon this figure.

Apparatus of the first order.

Intensity of the light from this apparatus - - - 630 burners.
Range in ordinary states of the atmosphere - - - 20.2 miles.

Figures 1 of Plate 1 represent the distribution, the intensity, and the range of the luminous rays emanating from an apparatus of this kind.

### 2. FIRST-ORDER APPARATUS FOR A FIXED LIGHT VARIED BY FLASHES EVERY FOUR MINUTES.

This apparatus differs from the preceding one only in having three lenses with vertical elements at equal distances apart revolving around the drum, which they encircle throughout its entire height. They each subtend an angle of 34° 12′, and collect into beams the luminous rays refracted by the cylindrical lens. The flashes which they produce are preceded and followed by eclipses of less duration than are most of those of other revolving lights. Besides, these eclipses are not total, except at great distances, since nothing obstructs the path of the rays transmitted through the catadioptric rings. The fixed light produced by the entire apparatus is followed by a well-marked dimness, which constitutes a total eclipse beyond the distance of 16 2 miles in an average state of the atmosphere, and the duration of which is about twenty-five seconds at a short distance; then follows a very brilliant flash, which is succeeded by an eclipse similar to the preceding one, followed by a fixed light.

Figures 5 of Plate 1 represent the distribution, intensity, and form of the luminous beams answering to these different conditions of the light.

The left side of Figure 1, Plate 6, shows a section of the apparatus taken through the axis of one of the vertical-element lenses, and Figure 3 is an elevation of one of these lenses. One-fourth of the horizontal section of the same apparatus occupies the angle B of Figure 1, Plate 4, the revolving machinery being shown at C.

Thus, as has been said in treating of the general arrangements of the illuminating apparatus, recourse is had to vertical-element lenses only for lights having a dead angle of not less than 45°. For those which are required to illumine the entire horizon, annular lenses are introduced in the drum, and the entire system revolves, as shown for the small apparatus on Plate 11.

Intensity of the fixed light, 630 burners; range, 20.2 miles.
Intensity of the light during the eclipses, 190 burners; range, 16.2 miles.
Intensity of the flash, 4 000 burners; range, 27.0 miles.

*Plate 3 gives, upon a large scale, the different lenticular profiles now in use.

### 3. FIRST-ORDER APPARATUS FOR A LIGHT WITH ECLIPSES EVERY MINUTE, (PROLONGED FLASHES.)

Figures 3 and 4 of Plate 5 give the plan and elevation of this apparatus, and half of its horizontal section is represented on the left side of Figure 1 of Plate 4. Figure 1 of Plate 7 gives, to the left, a section taken through the axis of one of the panels of the drum, and to the right, a section through one of the angles of the polygon. Figure 2 of the same plate is an elevation of one of the panels of the apparatus. The axes of each set of catadioptric rings make in horizontal projection angles of 4° with those of the annular lens of the drum below, so as to increase the duration of the flashes, while the lower catadioptric rings are arranged for a fixed light. The drum and the catadioptric crown only revolve. The revolving machinery is seen in elevation and section, and indicated at C on the plan.

Figures 2 of Plate 1 represent the distribution, intensity, and form of the luminous beams of this apparatus.

Intensity of the flash, 5 075 burners; range, 27.9 miles.
Intensity of the light between the flashes, 60 burners; range, 12.7 miles.

### 4. FIRST-ORDER APPARATUS FOR A LIGHT WITH ECLIPSES EVERY THIRTY SECONDS, (PROLONGED FLASHES.)

This apparatus differs from the preceding in that the regular polygon which a plan of the base makes, is composed of sixteen sides instead of eight. Figure 3 of Plate 7 represents one of its faces, and Figures 3 of Plate 1 show its effect.

Intensity of the flashes, 2 525 burners; range, 25.2 miles.
Intensity of the light between the flashes, 60 burners; range, 12.7 miles.

### 5. FIRST-ORDER APPARATUS FOR A LIGHT WITH ECLIPSES EVERY TWENTY SECONDS OR LESS.

The number of sides of the polygon is increased to twenty-four, and the luminous apparitions following in quick succession, it was not thought necessary to prolong the duration of the flashes, nor to preserve a fixed light during the intervals between them; each dioptric panel has two catadioptric annular panels placed upon the same axis with it. Figure 4 of Plate 7 gives the elevation of one of the faces of the apparatus, the whole of which revolves. The armature, the lower catadioptric panels, and the drum are arranged as shown on Figure 6 of Plate 5. In the revolving apparatus, which has just been described, the lower zone is fixed, which allows entrance to the interior either through a door the entire height of that part, or by an opening without the rings, which can be arranged when it is not necessary to illumine the entire horizon, or when the fixed light in a space of 45° may be dispensed with; but here the movement of rotation being given to the whole apparatus, it becomes necessary to have recourse to a special arrangement, so that the keeper may reach the lamp without arresting the motion of the apparatus. For this purpose the place of entrance has been lowered; the uprights which rest upon the chariot are brought together in such a way as not to obstruct the passage around the foot of the apparatus; they are only six in number, and three steps lead to the landing on the service-table.

Figures 4 of Plate 1 show the distribution, the intensity, and form of the luminous beams emanating from an apparatus of this kind. The upper figure shows to the left the flashes which succeed each other every twenty seconds, and to the right, flashes with only three seconds' interval between them.

Intensity of the flashes, 2 450 burners; range, 25.1 miles.

### 6. FIRST-ORDER APPARATUS FOR A LIGHT WITH ECLIPSES EVERY TWENTY SECONDS OR LESS, IN WHICH A RED FLASH ALTERNATES WITH A WHITE ONE.

This apparatus is represented in plan and elevation by Figures 5 and 6 of Plate 5. The panels of the lower zone and of the drum are twenty-four in number, and there are but twelve in the upper zone. Two of the first produce the white flashes, and to constitute red flashes one of the last is added to them. The color is given by pieces of red plate glass placed in the interior of the apparatus before the lenses Those of the first two zones are vertical; the others are inclined, and form a kind of pyramidal roof. All are fitted in light bronze frames, which open with hinge-joints.

Intensity of the white flashes, 1 825 burners; range, 24 miles.

Intensity of the three superposed panels when not fitted with red screens, 3 075 burners.

By calling to mind what has been said about the absorption of the luminous rays by color, it may be judged from these figures that under the ordinary conditions of the atmosphere the white flashes ought to have a little greater range than the red ones

In an apparatus of this description, which is used in the light-house at the Point of Créac'h, (Isle of Ouessant,) two white flashes alternate with a red one. The upper cupola is divided into eight panels, and the intensity of the colored flashes would reach 3 725 burners if they were white. About double the quantity of luminous rays is employed for the red flashes, from which it follows that the range of the two kinds of flashes is about the same. This last characteristic is in this respect preferable to the preceding.

The intensity of the red flashes of this apparatus might, it is true, be increased by applying to the lower zone the same arrangement that is applied to the upper; but that would have been at the expense of the white flashes, the intensities of which would be found insufficient.

### 7. SECOND-ORDER APPARATUS FOR A FIXED LIGHT.

Apparatus of the second order.

This apparatus is similar to that of the first order, differing only in dimensions and the number of rings.

The half plan of this apparatus is represented by part B of Figure 2 of Plate 4; the half section is seen to the right, upon Figure 1 of Plate 8. Figure 2 of the same plate gives the elevation of one of its panels, each of which embraces one-sixth of the circumference.

Intensity of the light, 335 burners; range, 18 miles.

### 8. SECOND-ORDER APPARATUS FOR A LIGHT WITH ECLIPSES.

Apparatus of the second order with eclipses are similar to those of the first order. The plan of the drum is a polygon of eight sides when the intervals are one minute, and twelve when they are thirty seconds. To prevent too great a reduction of intensity, the number of panels is not doubled as in the first order The apparatus in this case takes only six minutes instead of eight to complete an entire revolution, and the duration of the flashes is correspondingly reduced. These flashes are prolonged, as in the first order, by the panels of the cupola.

When the interval between the eclipses is twenty seconds and less, the number of panels is increased to twenty, the fixed light is suppressed, and the lense and all the catadioptric rings of a panel are placed upon the same axis.

In apparatus of the second order varied by flashes, the vertical-element lenses usually embrace an angular space of 43° 40′ and only cover the drum.

On the left side of Figure 2, Plate 4, and of Figure 1, Plate 8, is represented half of the plan and half of the section of an apparatus of the second order, the eclipses of which follow each other at intervals of thirty seconds. Figure 3 of this last plate gives the elevation of one of these panels.

Figures 7 and 8 of Plate 1 represent, respectively, the distribution, intensity, and form of the luminous beams emanating from apparatus of the second order—one with eclipses every thirty seconds, and the other a fixed light varied by flashes every three minutes.

*Intensity of the flashes of a second-order apparatus for a light with eclipses.*

Once every minute: 2 550 burners; range, 25.3 miles.
Every thirty seconds: 1 675 burners; range, 23.7 miles.
Every twenty seconds and less: 1 450 burners; range, 23.2 miles.
Intensity of the light between the flashes of the two first apparatus, 25 burners; range, 10.3 miles.

*Apparatus with vertical-element lenses.*

Intensity of the flashes, 2 700 burners; range, 25.5 miles.
Intensity of the fixed light, 335 burners; range, 18.0 miles.
Intensity of the light during the eclipses, 95 burners; range, 14.0 miles.

### 9. THIRD-ORDER APPARATUS FOR A FIXED LIGHT.

Apparatus of the third order.

The half plan and half section of this apparatus are represented on the left of Figure 3 of Plate 4, and Figure 1 of Plate 9.

Figure 2 of this last plate gives the elevation of one of the panels, which embraces one-fifth of the circumference.

Intensity of the light. 90 burners; range, 13.9 miles.

### 10. THIRD-ORDER APPARATUS FOR A FIXED LIGHT, VARIED BY FLASHES EVERY THREE MINUTES.

The half plan and half section of this apparatus are represented on the right of Figure 3, Plate 4, and Figure 1, Plate 9. Figure 3 of this last plate gives the elevation of one of the lenses of vertical elements, which embraces an angle of 41° 32′ and only covers the drum.

Figures 12 of Plate 1 represent the distribution, intensity, and form of the luminous beams of an apparatus of this kind.

Constant intensity of the fixed light, 90 burners; range, 13.9 miles.
Intensity of the light during the eclipses, 25 burners; range, 10.3 miles.
Intensity of the flash, 950 burners; range, 21.6 miles.

### 11. THIRD-ORDER APPARATUS FOR A FIXED LIGHT, VARIED BY FLASHES, WITHOUT ECLIPSES.

The arrangement which constitutes this new characteristic was applied, for the first time, to the light of Walde, the lantern and apparatus of which are represented upon Plate 10. The lower half of the drum and the catadioptric rings above and below constitute a fixed light, which spreads its rays upon the entire horizon except in the dead angle on the land-side. The upper part of the drum is composed of twelve annular half lenses; it revolves and produces the flashes, which succeed each other at intervals of twenty seconds. The apparatus is illuminated by a lamp with two wicks, consuming 175 grammes of oil per hour.

The interior diameter of the cylindrical drum is but 0.46 of a meter.

In order to render this light more characteristic, the annular half lenses of the drum are covered with red glass, and bands of the same glass, embracing an angular space of 9°, which corresponds to the divergence of these lenses, are placed above and below so as to color the fixed light and to prevent the blending of the white rays with the red. Figure 3 shows very clearly this arrangement.

This apparatus was constructed, not like the preceding ones of polished glass, but of glass run simply into molds prepared with great care.

Intensity of the light, 18 burners; range, 9.4 miles.
Intensity of the uncolored flashes, 270 burners; range, 17.3 miles.

Some more important apparatus, of later construction than that just spoken of, have been arranged in the same general way. One of them is represented in horizontal projection and elevation by Figures 7, 8, and 9 of Plate 5. The profile of its lenses is the same as was finally adopted for third-order eclipse lights. The part which constitutes the fixed light is composed of the lower catadioptric rings, and the cylindrical lens of the drum up to and including the first echelon which surrounds the central lens; its height is 0.80 of a meter. The movable part occupies the summit of the apparatus, and is formed of ten annular panels, which embrace all the upper catadioptric rings and the five upper echelons of the drum. The lenses of the drum are part dioptric and part catadioptric They are covered outside by colored glass, forming a drum having a decagonal base, which turns with it. Each face is extended downward by a small strip of glass, as in the apparatus of Walde, and for the same reason.

The panels are colored alternately red and green, and an entire revolution of the apparatus is made in three minutes and twenty seconds.

The apparatus then produces a fixed white light, varied at intervals of twenty seconds by flashes alternately red and green. The duration of each of these flashes is about two seconds at long distances

Intensity of the fixed light, 60 burners; range, 12.7 miles

The intensity of the flash, when not colored, reaches 420 burners in the axis, and falls to about 150 burners at 2° on either side. Under ordinary conditions of the atmosphere, the colored flashes have a greater range than the fixed light; in foggy weather, the green flashes are soonest lost in leaving the light, as has already been stated when treating of colored lights.

It may be remarked that the revolving machinery is placed in the pedestal which supports the apparatus; that arrangement will be spoken of again, as it has often been used of late.

If the colored glasses were removed, there would be a fixed light, varied at more or less frequent intervals by flashes, which would be neither preceded nor followed by eclipses.

Figures 11 of Plate 1 exhibit an apparatus of this kind in which the flashes are not colored.

## 12. THIRD-ORDER APPARATUS FOR A LIGHT WITH ECLIPSES.

The apparatus of the third order for a light with eclipses every minute or every thirty seconds differ only in dimensions from those of the second order with the same characteristics; the drum is composed of eight lenses in the first case, and of twelve in the second. It has not appeared necessary to give the drawings, as they can easily be imagined with the data already furnished the reader. Figures 10 of Plate 1 represent the distribution, the intensity, and the form of the luminous beams emanating from an apparatus of this class with prolonged flashes, in which eclipses succeed each other every thirty seconds.

When the interval between the flashes is twenty seconds and less, the drum has for its base a polygon of sixteen sides; the fixed light between the flashes is suppressed, and all the annular panels of each face are placed on the same axis, so as to give sufficient intensity to the flashes.

*Intensity of the flashes of a third-order eclipse-light apparatus.*

Once every minute: 845 burners; range, 21.2 miles.
Once every thirty seconds: 530 burners; range, 19.7 miles.
Once every twenty seconds and less: 590 burners; range, 20 0 miles.
Intensity of the light between the flashes of the first two apparatus, 7 burners; range, 7.2 miles.

## 13. THIRD-ORDER APPARATUS, (SMALL MODEL.)

This name is given to apparatus of 0.50 of a meter interior diameter, illuminated by a two-wick lamp which consumes 110 grammes of oil per hour.

Figures 13 of Plate 1 represent a fixed-light apparatus of this description.

Intensity, 30 burners; range, 10.8 miles.

Plate 11 represents one of these apparatus giving a fixed light varied by flashes. Instead of being produced by lenses of vertical elements passing in front of the drum, the flashes are produced by annular lenses, together with all the catadioptric rings. The eclipses which separate the fixed light from the flashes are total.

In other apparatus of the same characteristic, lenses of vertical elements which cover only the drum and the lower catadioptric rings are made use of. Figures 10 and 11 of Plate 5 give the plan and elevation of an apparatus of this description, in which the flashes succeed each other at intervals of two or three minutes, according to the velocity of rotation imparted by the revolving machinery.

Figures 15 of Plate 1 show the effect of one of these apparatus, in which the movable lenses cover only the drum, and in which the intervals separating the flashes are extended to three minutes.

Eclipse-light apparatus of the same dimensions have been constructed. Some of them are composed of six annular panels the whole or a part of its height, and their flashes usually succeed each other every minute. Others have ten panels, and the intervals between their flashes are as low as thirty seconds and less. Figures 12 and 13 of Plate 5 give the plan and elevation of an apparatus of this order, in which the eclipses follow each other every minute. The upper catadioptric rings are arranged for a fixed light, which appears between the flashes produced by the annular lenses comprising the drum and the lower catadioptric rings.

Figures 14 of Plate 1 represent the distribution, the intensity, and the form of the luminous beams emanating from an apparatus of the third order, (small model,) with eclipses every twenty seconds, in which the fixed light is produced by the lower catadioptric rings only. The intensity of the flashes reaches 175 burners, and that of the fixed light 2.5 burners.

*Intensity of the flashes of an eclipse light with a fixed light produced by the upper catadioptric rings.*

Once every minute: 275 burners; range, 17.4 miles.

Once every thirty seconds and less: 165 burners; range, 15.7 miles.

Intensity of the fixed light, 6 burners; range, 6.9 miles.

Intensity of the flashes of an apparatus with total eclipses, similar to that on Plate 11, 340 burners; range, 18.1 miles.

## 14. FOURTH-ORDER APPARATUS.

**Apparatus of the fourth order.**

Lenticular apparatus of the fourth order are of two principal sizes,—those of 0.375 of a meter and those of 0 30 of a meter interior diameter They are illuminated by single-wick lamps, the diameter of which varies from 0.24 of a meter (large burner) to 0.021 of a meter (small burner) when colza oil is used. Figures 1 and 2, 3 and 4, of Plate 12 represent the two sizes of these apparatus for fixed lights, illuminating three fourths of the horizon, and fitted with constant-level lamps. Recourse is had to moderator lamps when it is necessary to illumine the entire horizon.

There is nothing to prevent the establishment of eclipse lights of these small dimensions, but there are none on our coast. The lights of short range are almost always placed in such a position that it is of importance to mariners that they should always be visible, and that they should be less liable than others to lead to mistakes. They differ only in color, and sometimes by flashes succeeding each other every two, three, or four minutes.

In most of these apparatus lamps burning schist oil or petroleum, consuming 65 grammes per hour are used.

Figures 16 and 17 of Plate 1 show the effects produced, the first by a fixed-light apparatus 0.375 of a meter diameter; the second by an apparatus of the same dimensions, in which flashes, which follow each other every two minutes, are produced by lenses of vertical elements of the same height as the apparatus, and consequently accompanied by total eclipses.

Figures 5 and 6 of Plate 12 represent a small fixed-light apparatus 0.30 of a meter diameter, is made of molded glass. It has no catadioptric rings, but the height of the drum has been increased to 0.40 of a meter. Placed in a small lantern designed to be hoisted upon a spar, it is necessary to have it very light.

Apparatus of this kind do not admit of the use of schist oil on account of the currents of air to which they are exposed, and the intensity of their light does not exceed about six burners; but they are better, under all circumstances, than the sideral apparatus for which they were substituted.

One of the manufacturers, Mr. L. Sautter, constructs these apparatus of cut-glass, which are almost as useful as the others.

Figures 7 and 8 of the same plate give the elevation and section of an apparatus of molded glass designed for a range light. The rays which would otherwise diverge to the land-side are returned by a spherical reflector, the others are refracted by a large annular lens. Such of these rays as would strike the plane of the lens under too acute an angle are first deflected by a small conical lens.

Figures 9 and 10 represent the elevation and section of an apparatus of the same kind, constructed of cut-glass. It is also composed of a reflector and an annular lens; the lens is formed in part of dioptric and catadioptric rings. It has a greater intensity and less divergence than the other

Neither of these apparatus have come up to the expectations of their constructers; they are not as good as the large reflectors of 0.85 of a meter opening. The drawings have only been reproduced to state a fact and to anticipate objections.

Figures 11, 12, and 13 of Plate 12 give the plan, and front and side elevations of a reflector of one nappe (a photophore) with an opening of 0.29 of a meter, mounted on a pedestal, and illuminated by a constant-level lamp fed by colza oil. These small apparatus, which are very economical, are usually placed upon a table in front of one of the windows of the light-keeper's house, and are frequently employed for leading lights.

Lastly, Figures 14 and 15 represent a sideral apparatus fitted in a movable lantern.

*Apparatus* 0.375 *of a meter diameter for a fixed light.*

With a large-burner lamp: intensity, 13 burners; range, 8.6 miles.
With a lamp burning schist oil: intensity, 24 burners; range, 10.2 miles.

*Apparatus* 0.30 *of a meter diameter for a fixed light.*

With a small-burner lamp: intensity, 9 burners; range, 7.8 miles.
With a lamp burning schist oil: intensity, 18 burners; range, 9.4 miles.

*Apparatus* 0 375 *of a meter diameter, for a fixed light varied by flashes, movable lenses covering only the drum.*

With a large-burner lamp: intensity of fixed light, 13 burners; range, 8.6 miles.
With a large-burner lamp: intensity of flashes, 118 burners; range, 14.7 miles.
With a lamp burning schist oil: intensity of fixed light, 24 burners; range, 10.2 miles.
With a lamp burning schist oil: intensity of flashes, 221 burners; range, 16.7 miles.

Movable apparatus of cast-glass for a fixed light with a small-burner lamp, (Figures 5 and 6:) intensity, 6 burners; range, 6.9 miles.

Leading lights:

Figures 7 and 8, with large-burner lamp: intensity, 200 burners; range, 16.4 miles.
Figures 9 and 10, with large-burner lamp: intensity, 300 burners; range, 17.7 miles.
Figures 11, 12, and 13, with small-burner lamp: intensity, 60 burners; range, 12.7 miles.
Sideral apparatus: lamp consuming 45 grammes of colza oil per hour, (Figures 14 and 15:) intensity, 3.5 burners; range 5.8 miles.

## 15. FLOATING APPARATUS FOR A FIXED LIGHT.

Apparatus for floating lights.

Plate 13 represents an apparatus for a floating light (fixed) inclosed in its lantern. As has already been stated, this apparatus is composed of ten reflectors of 0.29 meter opening, each lighted by a constant-level lamp consuming 50 grammes of colza oil per hour. The burner is placed slightly out of the focus of the paraboloid in order that the luminous rays from each reflector may not be too concentrated and the light from the apparatus too unequally distributed in the horizontal plane. The curve *b b b* of Figure 9, page 49, shows the distribution of these rays. The maximum intensity is 38 burners, the minimum 18. The range varies from 11.4 to 9.4 miles.

Each lamp rests upon a small iron chair, to which it is attached by two clamps, and carries its reflector fixed in the same way. It is so arranged that the center of gravity of the upper reservoir is on the same perpendicular line as that of the lower cup when the reflector is in its normal condition—that is, when its axis is horizontal. This position is assured by means of a leaden weight placed under the cup. In order that it may maintain its normal position notwithstanding the motion of the vessel, each reflector is suspended so as to oscillate freely in every direction. The chair which supports it turns freely upon two axes in the same horizontal plane—one parallel, the other perpendicular to that of the paraboloid. The extent of the motion in each direction cannot exceed 60°. It is indicated on Figures 5 and 6 by dotted lines.

The suspension-rings of the ten lamps and reflectors are fastened to a horizontal circle made of bronze, which is moved by means of rollers upon a fixed circle of the same material, the cross-section of which has the form of an **L**. Lateral sliding-friction is reduced to rolling-friction by means of ten small horizontal rollers. The fixed circle is supported by four uprights, which form the frame-work of the lantern around the mast. The movable circle is held during the night by a clutch in such a position that each reflector is kept in the axis of one of the panels of the lantern.

This lantern has ten sides. It is 1.44 meters in diameter between two opposite uprights, and 1 meter in height exclusive of the cornice. Glazed in its upper part to a depth of 0.46 of a meter, it is closed everywhere else by sheet-copper, and each alternate panel below the glazing is provided with a double-leaf door. The glass of the panels which have no door can be lowered from the outside; for this purpose their frames slide in lateral grooves made in the uprights. By means of these doors the interior surfaces of the panes of glass can be reached to be cleaned; a pane is lowered for the purpose of lighting, and to remove or replace the reflectors, lamps, &c.

Ventilation is assured by means of ten ventilators cut in the bottom of the lantern having movable slides, which can be opened more or less as occasion requires; the products of combustion pass off through chimneys which are arranged as shown on Figure 2, Plate 13, so that the external air cannot enter the lantern with sufficient force to affect the steadiness of the flame.

The lantern can be raised and lowered upon the mast, guide-pieces being attached to its four interior uprights; two of these uprights have jaws which embrace the corresponding guide-rods. This arrangement is shown by Figures 1, 2, 3, and 4, Plate 13. Two vertical iron

rods which pass through the lantern are made fast to the lower circle by means of nuts, the suspension-chains being attached to their tops. The lantern is made entirely of bronze, except the panels, which are of copper.

The total weight of the apparatus and its lantern may be estimated at 830 kilogrammes.

Figure 1. Elevation of the lantern and apparatus.

Figure 2 Section taken on the line A B of Figure 3.

Figure 3. Sectional plan, through the line C D of Figure 2.

Figure 4. Sectional plan, through the line E F of Figure 2.

Figures 5, 6, and 7. Front elevation, lateral elevation, and plan of a reflector and its lamp.

### 16. FLOATING APPARATUS FOR A LIGHT WITH ECLIPSES.

An apparatus for a floating light with eclipses is represented on Plate 14. It has eight reflectors of 0.37 of a meter opening, each of which is illuminated by a constant-level lamp consuming 60 grammes of colza oil per hour, the flames being placed in the focus of the reflectors. The maximum intensity of the luminous beams emanating from one of these apparatus may, in practice be estimated at 100 burners, the divergence in the horizontal plane being about 30°. The range in the axis is 14.2 miles.

The lamps and reflectors are arranged in a manner similar to those just described. The motion of rotation is communicated to the circle which supports them by means of a large cog-wheel fastened upon the upper surface of the circle. This wheel, with cogs on the inside toward the mast, gears in a pinion attached to the top of a vertical hollow iron rod, the motion being communicated by means of another cog-wheel and pinion below. This machine is set in motion by a weight which gently slides between four iron guides. It is placed below the deck, at the foot of the mast.

The rod or shaft which transmits the motion is inclosed throughout its length above the deck in a half-cylinder of copper, which is fixed to a strip nailed to the mast. It is furnished on the lower end with a steel point, which turns in an agate set in the head of a bolt, by means of which it can be slightly raised or lowered. It is made in three or four pieces, which are held together by expansion box joints, which make all revolve when one does as though it was a single piece, but allow them to expand or contract without any alteration in the entire length, and to accommodate itself to the mast without stopping the motion when the latter bends a little under the action of the wind. A small door is made in the cylindrical covering of the shaft in front of each of the expansion-joints.

When the lantern is hoisted, its cog-wheel may not gear immediately with its pinion: the latter is then raised by the former, a spiral spring presses the pinion down and forces it into its place as soon as the teeth of each wheel take their proper relative positions, which is accomplished by means of a movement of the machine This spring is shown on Figure 6.

It was important to provide the means of keeping the lantern lower during bad weather than in good, which may be done in the following manner: A pinion similar to that at the summit is attached to the middle of the shaft; this pinion and the large cog-wheel of the apparatus are held in the proper relative positions whenever the lantern is raised or lowered, so that nothing opposes its passage, and the lantern may be stopped at either pinion. The clutches are raised before the machinery is put in motion

The lantern is constructed and arranged like the preceding one, except in regard to dimensions and the number of sides.

Figure 1. Plate 14, is a section of the lantern and of the mast taken along the line A B of the plan. The lantern is represented in the position it occupies during the night; the directing rod, the revolving machinery, and the motor weight are shown in elevation; and at *o* an alarm bell is shown, which is sounded as the motor weight approaches the end of its course.

Figure 2. Sectional plan through C D of Figure 1.

Figure 3. Sectional plan through E F of Figure 1.

Figures 4 and 5. Elevation and plan of the lower part of the directing-rod.
Figures 6 and 7. Elevation and plan of the summit of the same rod.
Figures 8, 9, and 10. Elevation, section, and plan, showing the arrangement of one of the expansion-joints.

## 17. ACCESSORY CONSTRUCTIONS.

**Revolving machinery.**

Revolving machinery puts the movable parts of illuminating apparatus in motion, weights being used as the motor, and the velocity regulated by a fly-governor. Usually placed by the side of the apparatus, the movement is communicated by a cog-wheel so arranged as to be thrown into or out of gear at will. The cord which sustains the motor weight passes through the arch of the floor which supports the illuminating apparatus, in an opening arranged for that purpose, and the weight, carried off by means of a roller and pulleys, descends in a vertical well in the side of the tower.

Some new apparatus have their revolving machinery placed in the pedestal, which has been enlarged in consequence. Figure 9 of Plate 5 shows an arrangement of this kind.

The weight in the revolving machine of first-order lights now in use is about 75 kilogrammes; it is hung by means of a system of blocks and falls, and the estimated rate of its motion is one meter per hour.

**Frames.**

The frames of the apparatus of the three largest orders are supported on hollow cast-iron columns, which are mortised at the base into the arch and crowned by the table of the apparatus. This table, formerly made of wood, is now made of cast-iron; on it the keeper stands when it becomes necessary to attend the lamp The tables of first-order apparatus are fitted with lockers, in which various small articles required in the service are kept.

Iron uprights united by tie pieces start from the table; they rise to the entire height of the drum, and the circle by which they are held together at the top serves as the support for the catadioptric panels of the crown. These panels are sustained in position by screws, and are surmounted by a cross-braced ring, which holds the centering pin in fixed apparatus, and carries the horizontal rollers which move around a vertical iron collar fixed to the lantern in revolving apparatus. In eclipse lights, the frame is movable in whole or in part, according to the arrangement of the apparatus.

The motion of rotation takes place upon a chariot with vertical rollers, which turn between the lower table of the movable apparatus and that which supports the top of the cast-iron column. The latter table was constructed formerly of wrought or cast-iron, and grooves were soon cut into it by the action of the rollers. It is now made of steel and the rollers of bronze. Horizontal rollers are introduced to reduce friction. The wear comes principally upon the rollers, which are easier to replace than the plate; this, however, is also so arranged that it can be removed. The vertical rollers may be moved out or set back; for this purpose, they are fitted with movable washers which can be applied to either of their faces.

**Lanterns.**

Lanterns are polygonal in plan. The table below shows their forms and usual dimensions:

| Order of light. | Number of sides. | Interior diameter between uprights. | Height of the glazing, including the ties. | Height of the cupola, including the ball. |
|---|---|---|---|---|
| | | *Meters.* | *Meters.* | *Meters.* |
| 1st | 16 | 3.50 | 3.32 | 2.53 |
| 2d | 12 | 3.00 | 2.60 | 2.29 |
| 3d | 10 | 2.50 | 1.90 | 1.88 |
| 4th | 8 | 1.60 | 1.12 | 1.16 |

The uprights, ties, and arches of the cupolas of lanterns of the three first orders are made of iron. The uprights are covered outside by a strip of bronze fastened by screws and pewter solder. The sills and cross-bars are of bronze. The cupola is formed of sheets of

copper fastened together and to the arches by small bolts, provided with battens, which are directed from the summit outward, and are first bolted then soldered in place.

The fourth-order lanterns are of such dimensions that the cupolas are constructed of one single piece and are simply fixed to the upper ties Iron is not used in the construction of these small lanterns. The uprights as well as the cross-bars are of bronze.

Heretofore the uprights were planted in the masonry walls, forming the sub-base or parapet of the lantern Now they are bedded into the interior face of this wall; this plan has the advantage of increasing the interior diameter of the parapet and the width of the small exterior platform upon which the keepers stand when cleaning the outside of the lantern glass. The first system is usually retained for the greater part of the small light-houses, where, on account of a lack of space, it is necessary to reduce as much as possible the diameter of the tower.

The ventilation of the lantern is a most essential object, and many plans have been successively adopted to render it as efficacious as possible The object is twofold: to furnish oxygen to the flame of the lamp. and to diminish the precipitation of moisture on the interior of the lantern glass, which reduces more or less the brilliancy of the light.

A chimney which is principally designed to carry off the products of combustion and the air which the flame puts in motion is fitted to the summit of the cupola. It is capped with a sphere pierced with vent-holes in its lower part In the lanterns of the three largest orders, the air necessary for proper combustion comes through the hollow column designed for the descent of the weights of the mechanical lamp, by the half-opened door of the stairway, and often by holes in the masonry sub-base of the lantern, the passage of the air through which is regulated by registers. Longitudinal apertures, which may be opened or closed at will, are also made in the lower sills of the lantern, and above each of them, at the foot of the cupola, is a small ventilating chimney, which assists in expelling the warm air and consequently in bringing in the cold.

Plates 6, 7, 8, and 9 show these arrangements.

A large copper basin is suspended in each lantern above the top of the apparatus, to catch drops of water which form either by filtration or condensation upon the cupola, and which might fall upon the flame or chimney. It is represented upon all the sections of lanterns.

The glazing is done with panes of plate-glass 0.008 of a meter in thickness. These panes are placed in the rabbets and kept in their positions by strips fastened by means of screws, both upon the uprights and cross pieces Care must be taken to give about 0.002 of a meter play all around the plate glass to prevent, as far as possible, breakage by the oscillations caused by tempests; they rest upon small pieces of lead, after which they are puttied all around.

Many panes of lantern glass have been broken, notwithstanding their thickness, by the shock of birds, such as ducks and geese, attracted by the brilliancy of the light. Nine panes of glass were broken in one night at the Cape Ferret light house. At the Bréhat light-house a wild goose passed between two courses of mirrors after having gone through the lantern pane, and fell upon the lamp. The lanterns of the lights which are most exposed to accidents of this kind are surrounded by fenders made of brass wire 0 0012 of a meter in diameter, with meshes of about 0 08 of a meter. This causes a slight diminution of the brilliancy of the light. It is to be remarked, however, that the number of birds which fly against the lanterns decrease from year to year after the first establishment of the light, so that probably the greater part of these fenders may at no distant day be dispensed with altogether.

All lanterns are provided with lightning-rods, with platinum points, made of large copper-wire rope.

**Lamps.** The arrangement of lamps will be described when an account is given of the principal properties of the combustibles employed.

## VI.—COMBUSTIBLES.

The light-houses of France are (1864) nearly all illuminated by lamps fed with colza oil. This oil is produced from colza, (*brassica campestris*,) which is cultivated in various parts of our country, but particularly in the department of the North and in Normandy. In the greater number of our fourth-order lights petroleum or schist oil has been introduced, and at one of our light-houses the electric light is now being tried. Other modes of producing light have been frequently proposed, but they have not yet been practically applied

### FAT OILS.

Experiments have been made at the Central Establishment of Lights upon the different oils which might be employed in light-house illumination, and it seems desirable to report them here; not only because they justify the preference given to colza, but because they appear to be of such a character that they can be profitably consulted in countries where considerations of economy may lead to the employment of oils otherwise produced.

These experiments were made in 1861 and 1862. The oils were furnished by Messieurs Guillou, Bucquet & Co. Each was of excellent quality of its kind, except the colza oil from India, for which was substituted, as soon as its interiority was discovered, the India colza oil which the corporation of the Trinity House of England uses in its light-houses.

The different oils tested were burned successively in small night-lamps, in single wick lamps, and in multiple-wick lamps. The trials were numerous, and the results will be found in the following table:

| Names of oils. | Where produced. | Duration of the combustion— | | Mean intensity for a consumption of 40 grammes and a duration of 8 hours in a lamp— | |
|---|---|---|---|---|---|
| | | In a night lamp. | In a lamp with 1 wick. | With 1 wick of 0.021*m.* diameter. | With 2 wicks of 0.039*m.* diameter. |
| French colza | North of France | 36*h* | 29*h* | 1.04*b* | 1.14*b* |
| India colza, from the corporation of Trinity House. | British India, oil manufactured in England. | 40 | 26 | 0.95 | 1.06 |
| India colza, (trade) | British India, oil manufactured in England. | 4 | 11 | 0.39 | 0.83 |
| Arachide, (earth-nut) | Senegal | 39 | 35 | 1.05 | 1.04 |
| Olive | Port Maurice | 40 | 23 | 1.07 | 0.89 |
| Spermaceti | North American fisheries | 27 | 29 | 1.05 | 1.01 |
| Cameline | French Flanders | 38 | 20 | 0.77 | 0.94 |
| Ravison | Black Sea | 28 | 23 | 0.82 | 0.84 |
| Linseed | Brittany | 18 | 14 | 0.87 | .... |
| Whale | North American fisheries | 15 | 18 | 0.86 | 1.05 |
| Sesamum | Syria | 14 | 26 | 0.73 | 0.85 |
| Cocoanut* | Cochin China | 55 | 41 | 1.06 | 1.18 |

* This oil, being in a solid state at the ordinary temperature, was heated to 35° before being introduced into the lamp, the temperature of the room in which the experiments were being made indicating 26° centigrade.

An absolute value should not be given to these figures, for the same kind of oil gives different results, according as it is new or old, and more or less purified. But with this reserve, we may deduce from them useful conclusions. It is seen that the different oils may be variously classed, according to the quality under consideration; that which burns longest in a night-lamp does not sustain combustion longest in an Argand lamp; and that which, for the same quantity consumed, gives the greatest intensity in a single-wick lamp, does not possess the same merit when used in a double-wick lamp. Thus, olive oil, which appears to possess advantages over colza when used in the former, was inferior to it when used in the latter.

The influence which the number of wicks exercises is more marked in lamps of the first order than in the others. Two of these lamps were fed, one with colza and the other with olive oil. After burning four hours the former presented a handsome flame, while the latter was with difficulty kept burning, and the mean luminous intensities per 40 grammes of oil consumed were raised, respectively, to 1.24 and 1.17 burners. These two lamps were left burning for three hours longer, and the flame of the olive-oil lamp fell off so that there was no longer any comparison, and it became necessary to trim it. This was done to the olive-oil lamp only, and the comparative experiment continued seven consecutive hours longer. The mean intensity of the colza-oil flame during that time was found to be 0.71 of a burner per 40 grammes of oil, while that of the olive-oil flame was only 0.53 of a burner. The difference would have been much greater if the wicks of the first had been trimmed at the same time as those of the second. This last fact tends to show that the olive oil deteriorates much more than the colza oil in passing through the burner, where it becomes heated.

Cocoanut oil gave excellent results in a first-order lamp After three hours' burning the flame was very brilliant, and had an intensity of 1.35 burners per 40 grammes of oil; and at the end of eleven hours, when it became necessary to trim the wicks, it had only fallen to 1.23 burners It produces a very small thief on the smallest wick. This oil is used in the light-house at Cape St. Jaques, in Cochin China.

Other elements than those under discussion should be taken into consideration in comparing these oils, viz: the price, and the temperature at which they cease to remain in a liquid state.

The following table shows the mean prices at Paris, (which however are subject to considerable variations,) the density, the co-efficient of expansion, and the temperature at which they congeal and liquefy. These last elements have been determined at the laboratory of the School of Bridges and Roads, by Engineer Mangon, with that precision which characterizes all of his experiments:

| Names of oils. | Price per 100 kg.* | Weight of cubic centimeter. | | Mean coefficient of expansion from +10° to +100° centigrade. | Approximate temperature. | | Remarks. |
|---|---|---|---|---|---|---|---|
| | | At +10° centigrade. | At +100° centigrade. | | Of congelation. | Of liquefaction. | |
| | *Frs.* | *Grammes.* | *Grammes.* | | ° | ° | |
| French colza | 122 | 0.9174 | 0.8583 | 0.000778 | + 3.1 | + 5.1 | The figures of the last two columns are not strictly accurate. The oil passes from the liquid to the solid state through degrees of viscosity which it is impossible to define. The results differ as the oil is at rest or in motion, and in large or small quantities. |
| India colza | †† | 0.9223 | 0.8634 | 0.000764 | + 4.0 | + 4.5 | |
| Arachide | 130 | 0.9199 | 0.8597 | 0.000784 | + 2.3 | +10.5 | |
| Olive | 160 | 0.9186 | 0.8479 | 0.000935 | + 4.0 | + 7.5 | |
| Spermaceti | 280 | 0.8844 | 0.8259 | 0.000793 | + 5.0 | + 8.0 | |
| Cameline | 115 | 0.9240 | 0.8650 | 0.000764 | + 1.0 | + 7.0 | |
| Ravison | 115 | 0.9202 | 0.8604 | 0.000778 | + 2.0 | + 6.0 | |
| Linseed | 110 | 0.9254 | 0.8654 | 0.000779 | + 2.0 | + 7.0 | |
| Whale | 110 | 0.9261 | 0.8654 | 0.000779 | — 5.5 | + 7.6 | |
| Sesamum | 130 | 0.9240 | 0.8636 | 0.000783 | — 3.0 | + 7.0 | |
| Cocoanut | 125 | 0.9343‡ | 0.8694 | 0.00098 § | +19.5 | +24.0 | |

* Price at Paris, not including custom-house duties.

†† This oil is not found in the trade at Paris.

‡ At 20°.

§ From 20° to 100°.

To recapitulate, the oils which appear to be the best for illumination, are colza, cocoanut, arachide, olive, spermaceti and whale.

The order in which they may be classed, according to the quality in view, may be indicated as follows:

| Duration of combustion in a lamp with one wick. | Intensity of the light in a lamp— | | Resistance to congelation. | Relative cheapness in France. |
|---|---|---|---|---|
| | With one wick. | With multiple wicks. | | |
| Cocoanut | Olive | Cocoanut | English colza | Whale. |
| Arachide | Cocoanut | French colza | French colza | Colza. |
| Spermaceti | Spermaceti | English colza | Whale | Cocoanut. |
| French colza | Arachide | Whale | Olive | Arachide. |
| English colza | French colza | Arachide | Spermaceti | Olive. |
| Olive | English colza | Spermaceti | Arachide | Spermaceti. |
| Whale | Whale | Olive | Cocoanut | |

Colza oil (French or English) greatly excels all the other oils in two essential respects—that of intensity of its light in multiple-wick lamps, (except cocoanut oil,) and of remaining liquid under ordinary temperatures It is not far from the best as regards duration of combustion and intensity of its light in single-wick lamps, and it is especially superior to olive oil in lamps with multiple wicks Finally, in regard to price, it is preferable to all the others, except whale oil, which is otherwise inadmissible on account of the short duration of its combustion and the necessity it imposes of frequently trimming the multiple-wick lamps.

It should be added that the multiple-wick lamps used in experimenting with these different oils were constructed to burn colza oil, and perhaps the other oils would have given better results in lamps whose forms were better adapted for burning them. No trials have yet been made in that direction for the reason that the colza has, in France, an incontestable superiority in several respects over the others; but the engineers of the Light-house Service intend to undertake them in the interest of our colonies, in which maritime illumination is about to be extended.

**Lamps.**

In all the lamps fed by colza oil the wicks are cylindrical, and are supplied with two currents of air, so that the combustion may be as active as possible. The glass chimney is contracted at a certain height above the burner so as to project the air against the middle and upper parts of the flame.

The number of wicks varies with the order of the light, as has been said before.

The following table shows the number and dimensions of the wicks, the consumption of oil, and repeats figures already given in regard to the flames and their luminous intensities:

| Order of light. | No. of wicks. | Mean diameter of wicks in millimeters.* | | | | Dimensions of the flame. | | Luminous intensity. | Consumption of oil per hour. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | No. 1. | No. 2. | No. 3. | No. 4. | Diameter. | Height. | | Per burner. | Per unit of light. |
| | | | | | | *mm.* | *mm.* | *b.* | *gr.* | *gr.* |
| 1st order | 4 | 22 | 43 | 64 | 85 | 90 | 100 | 23.0 | 760 | 33.0 |
| 2d order | 3 | 24 | 46 | 69 | ..... | 75 | 80 | 15.0 | 500 | 33.3 |
| 3d order .. large model | 2 | 19 | 39 | ..... | ..... | 45 | 70 | 5.0 | 175 | 35.0 |
| 3d order .. small model | 2 | 16 | 32 | ..... | ..... | 38 | 65 | 3.0 | 110 | 36.7 |
| 4th order .. large model | 1 | 24 | ..... | ..... | ..... | 30 | 45 | 1.6 | 60 | 37.5 |
| 4th order .. small model | 1 | 21 | ..... | ..... | ..... | 27 | 37 | 1.3 | 50 | 38.5 |

*Millimeter = 0.03937 of an inch.

It is seen that the multiple-wick burners are superior to the others in so far as the economy of light is concerned, since the luminous intensities increase in a greater proportion than the consumption of oil. The figures in the last column show this very clearly.

To prevent the burners from becoming too hot under the action of the heat to which they are exposed, it is necessary to cause much more oil to pass through them than is consumed, and that arrangement is besides favorable to the brilliancy as well as the steadiness of the flame. Experience has shown that at least three times as much oil should pass through the burners as is consumed. The lamps are regulated so as to cause to pass through the burner, per hour:

| | | |
|---|---|---|
| In the first-order lights - - - - - | 3.040 | kilogrammes of oil. |
| In the second-order lights - - - - - | 2.000 | " " |
| In those of the third order (large model) - | 0.700 | " " |
| In those of the third order (small model) - | 0.440 | " " |

Some keepers overrun these figures considerably, so as to manage their lights with greater ease; but it may be remarked that excess of feeding has the effect of raising, to a certain extent, the most brilliant point of the flame, which consequently renders it necessary to modify the distance to be maintained between the crown of the burner and the focus of the apparatus.

Plate 15 represents the different kinds of lamp-burners and the flames produced by them. These drawings are made half size. It was not considered necessary to include the small burners of the third and fourth orders.

Figure 1 gives the plan of a burner of the first order seen from above, and Figure 2 represents on one side the elevation, and on the other the section taken along the line A B of the plan

Figures 3 and 4, 5 and 6, 7 and 8 give, respectively, the plan, elevation, and the section of the burners and the flames of the second, third, and fourth-order constant-level lamps

These drawings show exactly all that enters into the composition of a lamp-burner; and it appears unnecessary to enter here into details, which are fully explained in the instructions for the Light-house Service.

Figures 9 and 10 show a lamp in which schist oil is burned, which will be noticed further on.

Most one-wick lamps, and some of those of the third order (small model) are of the kind called *constant level*. These lamps are too well known to require description. It is known that their reservoir is connected to the body of the lamp, and carries at its lower end a valve, which rises the moment it is put in place and opens communication with the burner. Below that valve is a small tube which regulates the height of oil in the burner, and its lower extremity should be kept at some millimeters below the crown of the latter. Capillary attraction causes the oil to rise in the wick.

This arrangement is inadmissible when the flame is required to illumine the entire horizon; recourse is then had to lamps with a reservoir below, in which the oil is forced up by mechanism. The only lamps of this description now used in fourth-order lights are *moderator lamps*. Their mechanism is placed in the reservoir, and consists of a spiral spring the base of which is fixed to a piston. This piston formed of an iron disk with a leather washer, is placed upon the oil and forces it up through a tube passing through the piston and ending below the burner. The movement of the oil is regulated by an iron stem fastened to the burner, which, sliding in this tube for a certain length, tends to draw out as the piston descends and the tension of the spring diminishes. An excess of oil flows into the burner and that which is not consumed flows back into the reservoir.

With the exception which has been spoken of above, all the lamps of the three largest orders are of the kind known as mechanical lamps.

Those which Messieurs Fresnel and Arago employed in their experiments in 1821 were constant-level lamps; the reservoir, higher than the burner, received air through a sliding

tube in a packing-box, which could be raised or lowered so as to regulate the level of the flow as required. But this system appeared to be ill adapted in practice, on account of the large space required both for the reservoir and for the cistern designed to receive the surplus of oil, and besides the necessity it imposed of having the oil frequently restored to the reservoir.

The mechanical lamps now most generally used in light-houses are of two kinds:

1st. *Clock-work movement lamp, system of Wagner.*—Its motor is an exterior weight which descends in the pedestal of the apparatus. An alternating movement of rotation is transmitted to two vertical shafts by means of cranks and geared wheels like those used in clocks. These shafts traverse the oil reservoir, and are provided with two levers fastened to their upper extremities, which work the feed-pumps. A fly-wheel regulates the motion. The supply of oil to the burner may be regulated also by turning a screw placed on the pump case and arranged so as to reduce (by being screwed in) the opening through which the oil passes.

2d. *Moderator lamp, with weights.*—A cast-iron piston, fitted around the circumference with leather packing, is weighted, and slides easily in the body of the lamp. A chain passing around a horizontal drum allows it to be wound up. It descends by the action of the weights, and thus causes an ascending movement of the oil in a vertical tube. The regulator consists of an orifice of small diameter, occupying the upper part of this tube, in which a conical needle penetrates, being pressed in more or less according as it becomes necessary to diminish or increase the flow. In some of these lamps the movement of the needle is regulated by that of the piston, so that the orifice opens as the piston descends, a greater pressure being required as the level of the oil is lowered.

Wicks.

The quality of the wicks exerts a marked influence upon the regularity of the flame, and especially upon its steadiness. It is essential that they should be woven of cotton of excellent quality; that their tissue be uniform, as flexible as possible, and neither too openly nor too closely woven. Specimen samples, adopted after a long series of experiments, have been deposited at the central Light-house Establishment in Paris, and all new wicks are required to conform strictly to them The woof is of cotton in wicks which should offer a certain degree of resistance, such as are required for sideral apparatus, which are not as well held up as the others; in others it is of silk.

The following table shows the width of the wicks when laid flat, the number of ends of each strand, the kind of woof, and the weight per meter of length:

| Order of light and number of wicks. | | | Width in millimeters. | Number of ends. | Kind of woof. | Weight per meter, in grammes. |
|---|---|---|---|---|---|---|
| 1st order | | wick No. 1 | 34 | 8 | Silk | 35 |
| | | wick No. 2 | 65 | 8 | Silk | 67 |
| | | wick No. 3 | 97 | 9 | Silk | 107 |
| | | wick No. 4 | 132 | 9 | Silk | 145 |
| 2d order | | wick No. 1 | 36 | 8 | Silk | 37 |
| | | wick No. 2 | 71 | 8 | Silk | 73 |
| | | wick No. 3 | 106 | 9 | Silk | 118 |
| 3d order | large model | wick No. 1 | 30 | 8 | Silk | 30 |
| | | wick No. 2 | 61 | 9 | Silk | 65 |
| | small model | wick No. 1 | 24 | 8 | Silk | 22 |
| | | wick No. 2 | 48 | 9 | Silk | 53 |
| 4th order | | large burner | 38 | 10 | Cotton | 42 |
| | | small burner | 33 | 9 | Silk | 36 |
| Siderals | | large burner | 38 | 10 | Cotton | 41 |
| | | small burner | 29 | 10 | Cotton | 32 |
| "Photophore," carcel burner | | | 30 | 8 | Silk | 32 |

The wicks of lamps for petroleum or oil of schist have cotton woof.

It is of great importance that the wicks be kept free from dust and dampness, to place them smoothly in the burners, and to trim them with the greatest accuracy.

Glass chimneys and dampers.

All lamp burners are inclosed in long glass chimneys with contracted necks. Above each chimney, enveloping the upper part without being fastened to it, there is a sheet-iron damper, used to regulate the combustion. In lenticular apparatus of the fourth order the damper is supported upon the crown-piece of the frame; in others it is kept in place by a sheet-iron case which is attached to the apparatus. This case is generally open at its upper end, and the products of combustion freely rise and escape outside, passing first through the openings in the chimney of the cupola, and afterward through those of the sphere which covers it, as shown by Figure 1 of Plate 9. In some light-houses this case is closed at the top, and three sheet-iron tubes, fixed upon its cover, are arranged for conducting the products of the combustion into the chimney of the cupola. This system is shown by Figures 1 of Plates 6, 7, and 8.

The chimney of the lamp is supported by a cylindrical holder, which can be raised or lowered by turning it to the left or right. When too high, the chimney renders the flame reddish with diminished brilliancy; when too low, it increases the brilliancy and diminishes the height of the flame. The same effects may be produced by the proper movement of the key of the damper. The flame lowers and whitens in proportion as the passage is opened; it rises, reddens, and tends to become smoky when the opening is reduced in size.

## OILS OF SCHIST OR PETROLEUM.

Some oils which have been used with great advantage within a few years past, both for domestic purposes and for lighting some of our small light-houses, are not included among those already spoken of, for the reason that they differ entirely from all others in several respects and cannot be burned in the same kind of lamps; these are the essential oils of schist or petroleum.

The first is produced by the distillation of bituminous schist; the second is produced principally in North America, where large quantities have been recently found. They are both hydro-carbons.

The densities of those which are best adapted to illumination vary from 0.80 to 0.83, taking the density of water for unity. When more dense they burn with difficulty, and have a tendency to disengage a thick smoke; when lighter, they are liable to cause serious accidents from their inflammability.

These oils, compared with the fatty oils, possess the triple merit of being *less expensive*, of producing *more light for the same amount consumed*, and of giving *lower flames and less useless divergence in small apparatus;* but they are more apt to smoke in case the supply of air is not properly regulated, and their manipulation requires much more care than the others.

From the numerous experiments to which these oils have been subjected the following conclusions may be drawn:

1. Oil of schist or petroleum of suitable quality gives an intensity of about one carcel burner for 30 grammes consumed per hour.

2. The lamps used in the Light-house Service, which have burners 0.0255 of a meter diameter, consume about 70 grammes per hour during the first hours of lighting, and only 52 grammes at the end of twelve or fifteen hours; for a well-attended lamp a mean consumption of 65 grammes per hour may be allowed, giving an intensity of 2.2 burners.

3. Petroleum and the oil of schist act about alike.

In estimating the price of colza oil at 1.51 francs per kilogramme, and that of petroleum or schist at 1.10 francs delivered at the light stations, it is seen that the unit of light costs 1.51 francs $\times$ 0.040 $=$ 0.06 of a franc with colza oil, and $\frac{1.10 \text{ francs} \times 0.065}{2.2} = 0.033$ of a franc with the others, not including the cost of wicks, chimneys, &c.

Two kinds of lamps are used for these new oils—one is the ordinary constant-level lamp, regulated so that the level of the oil remains at about 0.04 of a meter below the crown of the burner; the other consists of a simple reservoir into which the wick dips, and from which the oil rises by capillary attraction in sufficient quantity so long as the level does not descend to more than 0.16 of a meter below the burner.

The first consumes a little more oil, burns more steadily, and consequently gives a better flame, and continues more uniform during the entire combustion; but it is not as easily attended and is not adapted to lights required to illumine the entire horizon.

The burner of these lamps has a double current of air, but that is not sufficient to insure complete combustion—especially long continued—it is necessary to fit upon it a small brass disk, which throws the air upon the interior face of the flame and cools the wick. This arrangement is represented by Figures 9 and 10 of Plate 15. Figure 9 is a plan, and Figure 10 gives, on one side, the elevation, and on the other a section through A B of the burner and the reservoir. The screw for moving the wick is shown upon this section.

The chimneys are enlarged at the bottom so as to conform to the shape of the flame.

That shape necessitates a special profile for lens apparatus illuminated with petroleum or oil of schist, or at least a modification of the positions of the catadioptric rings, as we have seen in discussing the subject of illuminating apparatus

Some schist or petroleum lamps are supplied with flat wicks which dip into a lower reservoir. They have not the brass disk, and special forms for the chimneys are not required.

All efforts thus far made to apply oil of schist to the illumination of the three largest orders of apparatus have been unsuccessful.* We have not succeeded in giving much more intensity to the flame without causing it to smoke and rendering it very difficult to manage. Some success was obtained by blowing in air; but the system was not apparently susceptible of practical application, and was objectionable in other respects.

## GASEOUS COMBUSTIBLES.

Other modes of producing light have been proposed at different times, but they have not been thought worthy of adoption for light-house illumination, and it will be sufficient to mention them, showing briefly the reasons for their rejection.

Hydrogen gas produced by the distillation of bituminous coal is more economical than colza oil in about the same proportion as the oil of schist. It brings the price of the unit of light per hour to about 0.03 of a franc. The objections to it are, that it does not give a flame as brilliant on the surface as oil, and the danger of explosions The gas from oil produces a very beautiful flame, but it has not the advantage of economy, and is no safer than the other.

Oxygen gas, employed to intensify any flame whatever, has produced excellent results as regards the luminous intensity. The cost of this gas and the fear of explosions, however, have caused it to be rejected.

The oxy-hydrogen or Drummond light has many times been suggested, and modifications more or less beneficial have been made in it. The expense, the danger attending its use, and the irregularity of its flame have prevented, up to the present time, its practical use in light-houses; besides. its luminous intensity is not very great; it varied from three to six burners in the tests to which it was subjected.

## ELECTRIC LIGHT.

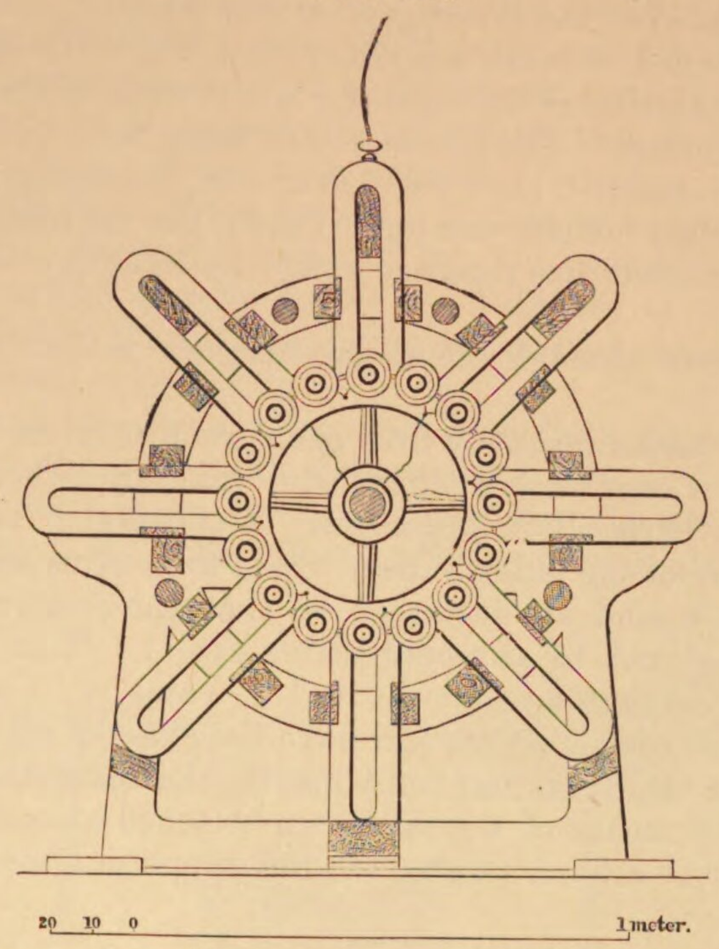
For a long time the electric light produced by currents from batteries of various kinds, especially Bunsen's, was experimented with. The results obtained were excellent so far as luminous intensity is concerned. but the skill required for managing the apparatus, the chances of extinction, the irregularity of the products, and the greatly-increased expense, did not seem to warrant the application of this mode of producing light for the illumination of light-houses.

*Since this was written lamps have been devised for burning mineral oil in all of the higher orders of apparatus. It is now used for those lights in France.—P. C. H.

A new arrangement, based on induction currents developed by magnets, was a great improvement, and, after having been experimented with for three years at the central Light-house Establishment at Paris, it has just been applied as an experiment at one of the first-order fixed lights at Cape La Hève, near Havre.*

The magneto-electric machine which produces the currents† is represented in section by Figure 25, below. It is composed of forty horse-shoe magnets, distributed in five equi-distant vertical planes upon the faces of a right prism with an octagonal base, and of induction spools passing between the groups of magnets and arranged close to them. These spools are fixed upon the circumferences of vertical disks which revolve around the axis of the prism and are put in motion by a small steam-engine. There are thirty-two spools, eight to each disk, as there also are eight magnets in each vertical plane. The magnets in each group are set with reference to each other, so that a spool always comes between two opposite poles, and a current is produced in the wire wound around it whenever it approaches a magnet, then is reversed when it leaves it. Sixteen changes of direction take place at each revolution of the cylinder. The maximum intensity was obtained when the machine made from 350 to 400 turns per minute, and the current then changes direction nearly one hundred times per second. The partial currents of the same kind are united and alternately put in communication with the one and the other of the cheeks of the cast-iron frame of the machine, which are separated by insulating substances. The conducting wires are attached to the summit of these cheeks, which take, successively, the combined currents to conduct them to the electric lamp. These wires are covered by an insulating material throughout their entire length. Mechanism.

FIG. 25.




The magnets are each of 60 kilogrammes' power.

The steam-engine is one of high-pressure, and of nearly four-horse power when the tension of the steam in the boiler is carried to six atmospheres, but four and a half atmospheres are sufficient to give the normal velocity to two machines similar to that described. Steam is generated from fresh water collected in large cisterns

The carbon-points between which the light is produced are supported and maintained at a proper distance by a regulator or electric lamp. The object of this apparatus is to bring Regulator.

* Since that time it has been tried at the other light-house, and at the present time each has the electric light.—P. C. H.

† This machine was furnished by the Alliance Company, which has a patent for it.

the two points as they are consumed near to each other without their coming in actual contact, which would cause an extinction of the electric spark. Numerous ingenious arrangements have been devised for this purpose. All of them are based upon the principle of the intervention of an electro-magnet traversed by the currents. That adopted for the illuminating apparatus of the light-house at La Hève was devised by M. Serrin. It is made as follows:

Two carbon-point holders are each attached to a vertical rod which slides in a guide-tube. These rods are so connected one to the other that when the lower one rises the other descends, the latter being moved by its own weight. This movement is regulated by a fly and cog-wheel. The guide-tube of the lower holder is supported by a double-articulated parallelogram, fitted with a small stop, which, according as it descends or rises, engages one of the wheels and stops the movement, or leaves it free and allows the carbon points to approach each other. This parallelogram is subjected to two opposite forces,—one, produced by a spiral spring, tends to raise it, the other, due to two electro-magnets which the current traverses, tends to lower it, attracting an armature fixed to the lower part of that piece.

The apparatus is arranged in such a manner that when the carbon points are at the desired distance for the production of the light the wheel-work is clutched, which insures the immobility of the carbon holders. The distance increasing with the combustion, the current becomes weaker, the electro-magnet loses its power, the parallelogram yields to the spring and raises the stop, the carbon holders are immediately put in motion, approach each other, and do not stop until the current has regained sufficient intensity to arrest the movement of the works.

The current which passes through the electro-magnets is that which flows to the lower carbon point.

Although the currents pass alternately from one carbon point to the other, experience has shown that the lower one is consumed a little faster than the other, but in a variable ratio, because the material is not perfectly homogeneous; it appears to be about as 100 is to 108. Consequently, the diameters of the pulleys upon which the chains used to combine the movements of the two rods are wound, are regulated so that the position of the luminous focus does not change, or at least not to any appreciable extent. That effect has only recently been verified, and was not estimated at first at its true value.

The consumption of the carbon points will have the effect of altering the existing relation between the weights of the two rods, and consequently the movement of the system. That defect has been remedied by means of a small chain attached at one of its extremities to the lower rod and at the other to a fixed point; the rod supports a longer part as the carbons become shorter.

Other details should be mentioned:

1. A button acting on the arm of a lever which holds two pulleys, around which passes the chain of the two rods, allows the luminous focus to be raised or lowered as may be required in practice, without interrupting the movement of the mechanism.

2. Another button acts upon the spiral spring in such a way that the machine may be easily regulated to suit the intensity of the current. It is evident that the spring ought to be stronger as the opposing current is more powerful.

3. Stops properly placed at different parts of the system limit the extent of the movement.

4. A small arm, turning around the summit of the upper guide-tube, allows the carbons to be placed exactly in position, and at the desired distance, and the upper carbon may be brought exactly in the axis of the other by means of buttons, which regulate the movements of the guide-tube in every horizontal direction.

5. The carbon holders are liable to burn, if, after the consumption of the carbon points, they come too near each other; the machine is so fixed that they cannot get nearer than 0.06 of a meter.

6. A copper box covers all of the machinery and protects it from dust and moisture.

This machinery is sufficiently complicated, though not so much so as might be supposed from a description, and is somewhat difficult to follow without having the pieces before one's eyes; but it is solidly made; each of its parts offers more resistance than is rigorously necessary, and it appears to be of a kind which is not difficult to attend, and does not require frequent repairs. It satisfies all the special conditions demanded of it in practice.

A new regulator is now being tried by the light-house engineers, and everything leads to the hope that it will give better results. Conceived by M. Faucault, (to whom electric illumination owes already a most ingenious automatic apparatus and the substitution of retort carbons in place of those hitherto employed,) it has been most carefully constructed by one of our most skillful artisans, M. Duboscq. The mechanism consists of a differential movement affecting two wheels, which may be geared either simultaneously or alternately by the pallet of the bent lever, moved by the regulating coil so as to cause the arrest, approach, or recoil of the carbons automatically. The apparatus is extremely sensitive.*

Electric light at La Hève.

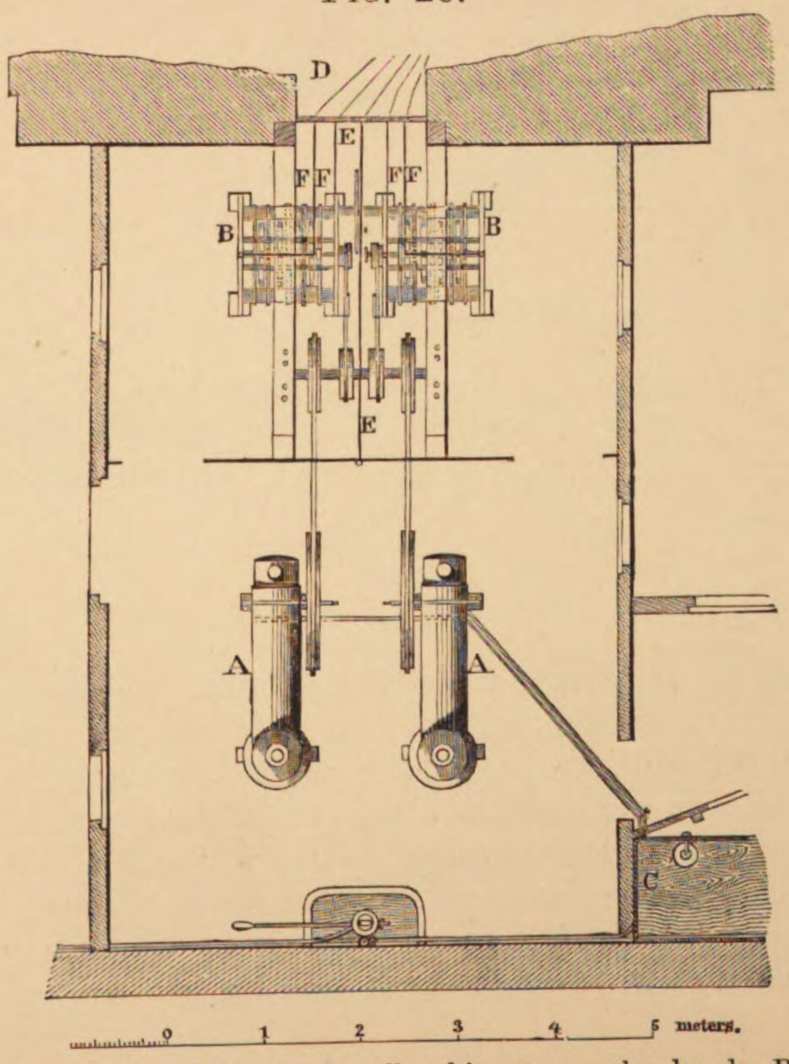
The uninterrupted exhibition of lights, which is of primary importance in light-houses, requires the adoption of proper measures to anticipate any extinctions to which they may be liable, whether on account of the necessity for renewing the carbons or of accidents to the machinery or the electric lamp. It has been deemed prudent to have in the same establishment a double set of all the parts of the system. By this arrangement there is the additional advantage of being able, if desired, in time of fog, for example, to put the two magneto-electric machines in motion and thereby double the brilliancy of the light.

The arrangements adopted for the light-house at La Hève, which illuminates three-fourths of the horizon, are as follows:

Two steam-engines and two electric machines have been placed, as shown by Figure 26, in a temporary building on the west front of the south tower.

A A, steam-engines; B B, magneto-electric machines; C, water tank and store-room for coal below; D, the tower; E E, india-rubber speaking-tube leading into the lantern; F F, conducting wires.

FIG. 26.




* This new regulator did not work well and its use was abandoned.—P. C. H.

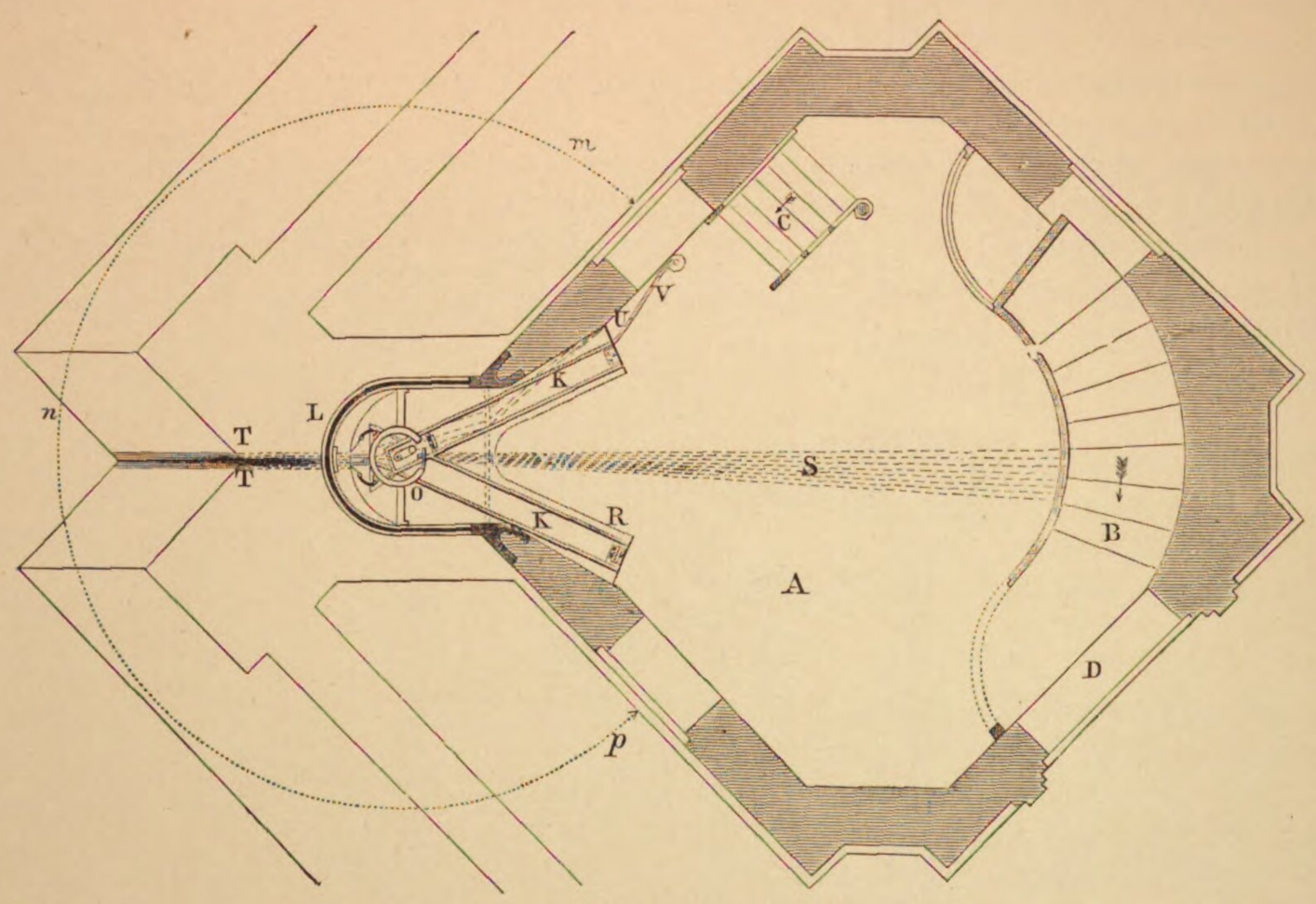
The two electrical machines may be put in motion separately, or both together in such a way as to be operated by a single motor. For that purpose a very simple mechanism allows the two axes to be connected or separated.

The conducting wires ought to pass up through the interior of the tower; but, in awaiting the completion of the work, they were placed in a vertical case outside, fastened in one of the reëntering angles of the structure. They are kept in position by porcelain insulators.

The lenticular apparatus are placed one over the other in the same lantern, which projects from one of the angles of a square room, divided into two stories, which takes the place above the platform of the tower of the old lantern and its base, (see Plate 19,) and has been put outside, in harmony with the rest of the structure. The plan (Figure 27) shows this arrangement.

A, lower room; B, stairway of the tower; C, steps leading to the upper room; D, door to the outside platform; K K, railways for the regulators; L, the lantern; O, illuminating apparatus; R, spare regulator; S, luminous rays emanating from the small lens; T T, conducting wires; U, switch; V, speaking-tube. The amplitude and the position of the sea horizon are represented by the arc of the circle *m n p*.

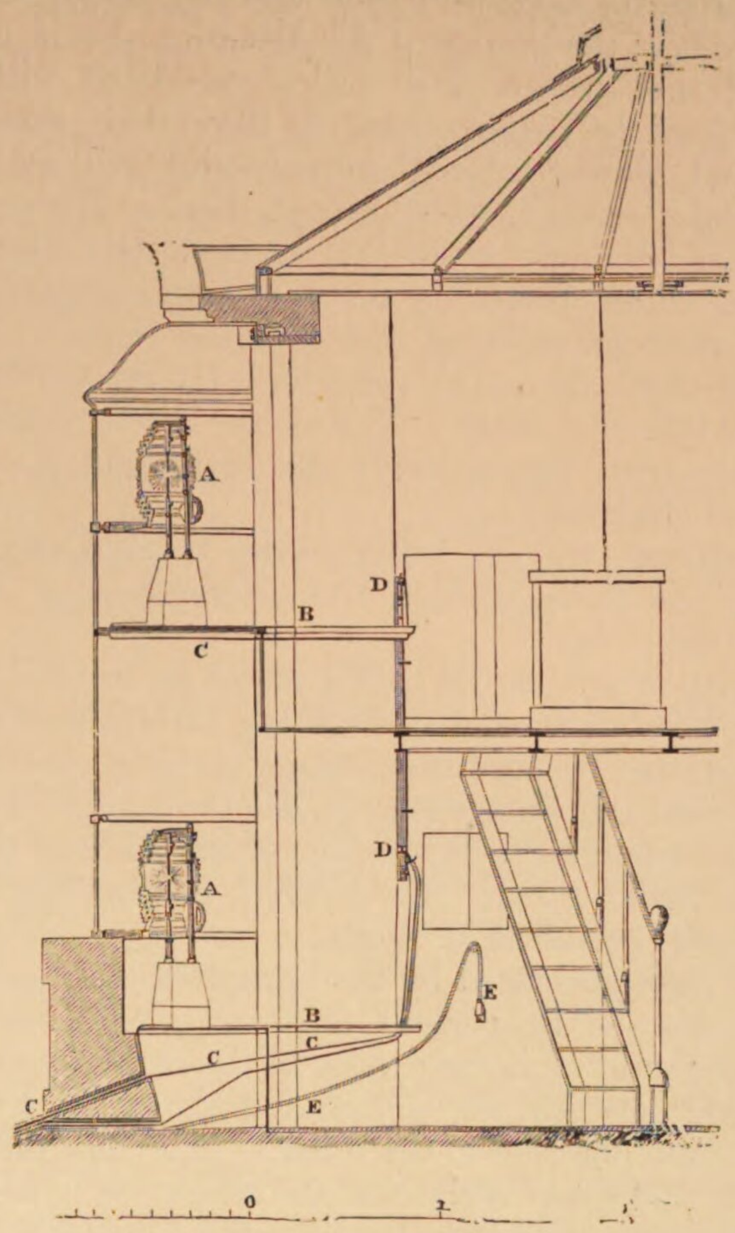
FIG. 27.




The lantern rests at its base on a mass of masonry, and is sustained laterally by two uprights of cast-iron, secured at the bottom, tied at their summit by a lintel of the same material, and fixed upon the walls which they terminate. The plate-glass of the lantern is curved, and kept in place above and below by bronze sashes, without being held laterally by vertical uprights, which would cause occultations on account of the small diameter of the flame. This glazing is composed of two parts, each placed to the right of one of the lens apparatus, and not more than 0.55 of a meter in height. The rest of the lantern is formed outside by bands of sheet-iron which give rigidity to the system.

The vertical section, which is taken through the axis of the apparatus, (Figure 28,) shows the arrangements made.

FIG. 28.




A A, the illuminating apparatus; B B, railways for the lamps or regulators; C C, conducting wires; D D, switches; E E, speaking-tube.

The apparatus are open for one-fourth of the circle, and may be turned around to facilitate cleaning.

Two electric lamps are assigned to each apparatus; they enter by sliding upon the small railways which cross each other, and are supported by a cast-iron service table; they stop when they reach the desired point, then take the currents and instantly light. For that purpose the iron table is in communication with one of the conducting wires and the other wire in contact with a flat spring fixed on that table below the lens apparatus, with the interposition of an insulating substance, and presses with elastic teeth a metallic plate placed under the lamp. This plate conducts to the electro-magnets the current which it receives. The other current is introduced into the body of the lamp, passing by the railway. The time necessary for the substitution of one lamp for another does not exceed two seconds.

The existence of a duplicate apparatus, always ready for use, also gives a means of preventing, for even a short time, the extinction of the light which that operation causes whenever the lighted lamp is to be removed for renewing the carbons, or any other cause; a switch placed under the control of the keeper enables him instantaneously to shift the current into the other apparatus, and the intensity of the light is diminished for only a very short time. The entire operation is executed with the greatest facility.

It is very important, in view of the restricted dimensions of the light and of the illuminating apparatus, that the position of the luminous focus should vary only within very narrow limits, a vertical displacement of 0.005 of a meter in either direction would cause the beam of light emanating from the apparatus to be elevated or depressed about 2°, and no ray would be carried to the limit of the horizon if the deviation should reach 0.008 of a meter.

Now, admitting that the keepers will notice variations within the limits of some millemeters, it would be hard to require them to have their eyes constantly upon a light of such great intensity that glasses colored green or blue will not relieve unless of so deep a color that an ordinary light cannot be seen through them. The service has been facilitated, and one of the gravest disadvantages attendant upon electric illumination, partly remedied by means of a small lens, which, placed in the dead angle of the apparatus, throws against the opposite wall of the room an enlarged and inverted image of the light, (S, Figure 27.) The enlargement is such than an actual variation of 0.001 of a meter corresponds to a represented variation of 0.022 of a meter. The keeper is not required to look at the electric light, but at the image, to satisfy himself as to the working of the apparatus, and the least deviation shows itself with clearness.

Attempts have been and are yet being made, to regularly register the extinctions and the displacements of the focus, without the intervention of the keeper, upon a paper sensitive to the action of light.

Carbons.

The carbons are square in section 0.007 of a meter on the side; they are 0.27 of a meter long, which gives to each 0.20 of a meter for burning, the remainder being lost on account of the holders covering a part, and because they cannot come in contact.

Their quality has a great influence upon the length of time they burn, and also on the intensity of the light. Those which are now employed are made of the densest carbon deposits which form in retorts for distilling coal. Their mean consumption may be estimated at 0.05 of a meter per pole per hour, exclusive of waste.

Luminous intensity.

The intensity of the light generated by the apparatus just described is subject to great variations, caused not by the electric current, (that is constant so long as the velocity of motion is the same,) by for want of homogeneity of the carbon points, slight modifications in the form and the distance between the points, and above all, by the displacement of the voltaic arc, which moves from one side to the other. It is very difficult to measure it by the photometer, for the reason that these variations are incessant; however, it has been done with such precision as could be had. Practically the mean intensity may be estimated at 125 burners, its maximum 180 burners, and its minimum about 75 burners. Placed in an apparatus for a fixed light like that at La Hève, which is represented on page 66, (Figure 22,) this luminous focus gives a divergence of about 6° in the vertical plane, and a mean intensity in the most illuminated plane, estimated at 3 500 burners, deducting the rays absorbed by the plate-glass of the lantern.

The electric light has not yet been applied to eclipse-light apparatus, but there is no serious difficulty in doing so. The intensity of the flashes will vary with the angular space which the lenses embrace, and might reach 30 000 burners.

Comparative merit of the electric light.

To estimate the advantages of the electric light, in so far as relates to expense, the comparison should not be limited, as has been done for the schist oil, to ascertaining the cost of the combustible consumed. This light necessitates the purchase of expensive machinery, &c., as well as attendance upon apparatus other than the lamps, and these two sources of expense cannot be omitted.

It seems that the calculation should be as follows:

| Cost of first establishment— | Francs. |
|---|---|
| Magneto-electric machine of four disks - - - - | 8 000.00 |
| Steam-engine and accessories - - - - - - | 3 000.00 |
| Regulator, conducting wires, &c. - - - - - | 1 500.00 |
| Total - - - - - - - - - - | 12 500.00 |

Calculating interest and deterioration of machinery at ten per cent., allowing, as in our lights. 4 000 hours of combustion annually, and allowing two firemen to the steam-engine, the expense per hour will be found from the following figures:

| | Francs. |
|---|---|
| Interest and deterioration, 1 250 francs, will be per hour - - | 0.3125 |
| Fuel for the steam-engine, 10 kilogrammes at 40 francs per 1 000 kilogrammes - - - - - - - - - - | 0.4000 |
| Salaries of two firemen, 2 800 francs per annum, and per hour - | 0.7000 |
| Salaries of two keepers, 2 000 francs per annum, and per hour - | 0.5000 |
| Carbon, 0.16 of a meter per hour, including waste, at 2.25 francs per meter - - - - - - - - - - | 0 3600 |
| Lubricating oil, water, repairs, &c. - - - - - | 0.1275 |
| Expenses per hour - - - - - - - - | 2.4000 |

The mean luminous intensity being estimated at 125 burners, the cost per single burner per hour for the unaided light comes to 0.0192 of a franc.

The cost of the same quantity of light, when furnished by a first-order lamp fed by colza oil, may be estimated as follows:

| | Francs. |
|---|---|
| Interest and wear, ten per cent. per annum, will be 65 francs, and per hour - - - - - - - - - | 0.0163 |
| Salaries of two keepers as above - - - - - - | 0.5000 |
| 760 grammes of oil per hour, at 1.51 francs per kg. - - - | 1.1476 |
| Wicks and glass chimneys, 1.9 francs per annum, and per hour - | 0.0298 |
| Repairs, waste, &c. - - - - - - - - - | 0.0583 |
| Expense per hour - - - - - - - - | 1.7520 |

The luminous intensity being equal to 23 burners, the cost per hour per burner is 0.0762 of a franc.

If the cost of the unit of light obtained with colza oil burned in a lamp of the first order be represented by 1, the electric machine will give the same quantity of light for 0.252.

The latter mode of production is nearly four times as economical as the other, under the conditions which have served as a basis of our calculations. If the source of the electric light were of less intensity, the cost of the unit of light would be increased, because the principal elements which constitute it are independent, within a certain limit, of the quantity of light produced; and, on the other hand, if more intense currents are produced, the cost per hour is increased, but the cost of the unit of light is reduced. One of the disadvantages of electric light in the present state of things is that it is not economically adapted to lights of feeble intensities.

To estimate fairly the advantages of this light for purposes of light-house illumination, it will be necessary to include in the account the cost of the lens apparatus and duplicate machinery, as well as the cost of construction necessary for establishing the machinery and the quarters for the firemen, and to take into account the advantage it is to navigation to have the intensity of the light increased. It is not deemed necessary to enter into a discussion of this subject, since the conclusions must vary according to the circumstances which each particular case presents, and the figures, as well as the methods of calculation shown in this memoir, furnish all the other elements of questions of this sort which may come up.

It is, nevertheless, to be remembered with reference to this subject, *that lights of different kinds to which the photometer assigns the same intensity have not always the same range.* When the question of colored lights was under discussion, it was seen that the red rays pass more freely through the atmosphere than the white ones, while the reverse seems to be the case with the green ones, so that the range depends both upon the intensity and the nature of the light. A luminous focus may be very brilliant and yet have but a very limited range during certain fogs if it be deficient in the red rays. An experiment made by the engineers of the Light-house Service upon a new mode of producing the electric light invented in England supports this assertion. A thin fillet of mercury falling into a capsule was substituted for the carbon points; the light had an intensity about equal to that obtained with them, and the two apparatus, the one of mercury and the other of carbons, lighted simultaneously, appeared equal at the distance of 1500 meters in a clear atmosphere. But red-colored glasses having been placed before them, the first was almost completely extinguished, while the other retained a very handsome brilliancy. The green color produced an entirely different result, as was expected; the light from the carbons was not extinguished, but was not as brilliant as the other. It was concluded from these experiments that, desirable as it might be in many respects, the system was probably not of a nature to be judiciously applied to the illumination of light-houses, and the inventor has not kept the promise which he made to submit his system to new trials at the season when fogs usually occur.

Observations made upon the electric light actually in use, both at long and short distances, tend to establish the conclusion that it is inferior, in respect to its composition, to the light produced by colza oil. These experiments are still in progress, for they are not yet sufficiently numerous to warrant the enunciation of formal conclusions.

# CHAPTER III.

## LIGHT-HOUSE STRUCTURES.

### I. GENERAL FEATURES.

There are no light-houses of antiquity now in existence; but from old medals and passages in ancient history we are able to form an idea of what they were.

They were established, for the most part, at the entrances of sea-ports; each great maritime city had one, and they were regarded as most remarkable monuments, as well on account of their height as the magnificence and solidity of their construction.

The most celebrated of all was that which Ptolemy Philadelphus had built on the Isle of Pharos, at the entrance to the port of Alexandria

Ranked as one of the seven wonders of the world, it has transmitted to all edifices of a similar kind a name which it derived from its location, or which perhaps the island on which it stood derived from it, viz: *Phrah*, Sun. Unfortunately, only insignificant vestiges of it remain, and the information given of it by historians is not sufficient to give an idea of its general features, nor permit the designs to be worked out with any degree of accuracy. It appears certain, however, that the tower was square in plan, very high, and was built up in several offsets. Édrési, an Arabian geographer in the early part of the 12th century of the present era, said that it had in his time a height of 100 brasses, (600 feet,) it being 576 feet to the base of the lantern. He estimated the height from the ground to the middle gallery at 420 feet, and that from this point the tower was built up in successive offsets in such a manner that there was space to walk around it at different elevations. The same writer adds that it was constructed of an excellent quality of building stone, fastened together with molten lead in a manner to form an indestructible mass, and that the light was visible at a distance of 100 miles. This range could only have been obtained under peculiarly favorable circumstances of atmospheric refraction, because the height assigned to the structure could not, under ordinary circumstances, give a range nearly so great; but we may doubtless infer that the light could be seen a long distance from the coast.

It is known that the architect of this monument, Sostrates of Gnidos, had cut on the walls of the tower the following inscription: "*Sostrates of Gnidos, to the gods who protect those who are upon the sea.*" According to Lucien, he was careful to hide these words under a coating of cement upon which he inscribed the name of Ptolemy, counting upon the action of time to reproduce his own. Pliny, on the contrary, praises the sovereign for giving the honor to the architect; but this seems very doubtful, for Ptolemy would scarcely have allowed that the architect should have figured as consecrator.

Denys de Byzance speaks of a light-house at the mouth of Chrysorrhoas, in the Thracian Bosphorus, and he adds that the inhabitants of the country lighted other fires on points of the coast for the purpose of deceiving mariners. These criminal practices were revived at a later period at other places, but no civilized nation of the present time is thus dishonored.

Suétoneas reports that the emperor Claudius had a light-house built at Ostia in imitation of that at Alexandria.

In the seventeenth century there was still to be seen a light-house of Roman construction near Boulogne, on the coast of France, which was probably built by Caligula at the time of his expedition into Gaul. Montfaucon says that it was destroyed in 1644, by the caving in of the cliff, and he gives a sketch of it, which is not without a certain stamp of authenticity. The plan of this tower was octagonal, and composed of twelve sections, one above the other, each section being somewhat less in diameter than the one below it, and had a cornice which formed a small exterior gallery on each, in a manner similar to that of the Alexandria light-house. Each side of the octagonal base was about 8 meters in length. As to the height there is no definite information given, but if reference be made to the sketch of Montfaucon it would be estimated at about 60 meters. The construction was executed in varied courses in regular order: first, there were three courses of Boulogne gray stone, then on top of them two of a softer yellow stone, then two courses of large brick of a deep red color, then the gray stone again, and so on. This light-house appears to have been restored by Charlemagne, who relighted the fires which had been neglected by his barbarous predecessors, but it was abandoned at a later but unknown period.

Near Dover there are the ruins of a tower of supposed similar construction to that of Boulogne, and which is supposed to have been built at the same period and for the same purpose.

In the middle ages the name of phare was given to small towers built in cemeteries,* some of which exist still; but it does not appear that any care was given to the lighting of sea-coasts; the great movement of the Renaissance was necessary to revive, in this respect as in many others, the wholesome traditions which had been unfortunately forgotten.

**Light-house of Genoa.**

In the sixteenth century the republic of Genoa had constructed at the entrance of the port of that city a light-house, which is even now regarded as among the finest structures of its kind. It is composed of two superposed towers with a total height of about 63 meters. Both are square in plan, the lower being 9, and the upper 7 meters on a side.

**Light-house of Cordouan.**

The tower of Cordouan, constructed at a somewhat later period, is the most remarkable of all existing monuments consecrated to the illumination of the sea-coast. It is built at the mouth of the Gironde river, coast of France, on a rock which is covered with about 3 meters water at high tide.

Commenced in 1584, under Henry III, it was finished in 1610; but it has been several times extensively repaired and considerably enlarged Plates 16, 17, and 18 represent it in its present state. The first gives sectional plans taken at various altitudes, the second is a section through the axis of the tower, and the third is an elevation.† In order to show the front of the tower entire one-half of the surrounding wall in the last design is supposed to be removed.

This edifice in its primitive state was not as high as it is at present. It was formerly composed of a circular platform protected by a heavy parapet, and of the tower, which was divided into four stories, not including the lantern. The ground floor had on it a grand hall, square in plan, and four small rooms which were used as sleeping apartments and store-rooms. Stair-cases placed in the side walls of the main entrance and of the two window embrasures led into the cellars and the cistern. The entrance to the grand stair-case was immediately in front of, and opposite to the entry hall. On the second floor, to which was given the name (probably not well deserved) of the *apartments of the King*, was a room of the same dimensions as the grand hall below, but more richly decorated, and from it the first exterior gallery

*At night the lantern of the dead was placed on the summit of a hollow column, a light burning in it indicated to strangers that it was a burial ground. This light was intended also to keep away evil spirits, vampires, and werewolves, which were a source of terror to the people of the North and West. (Dictionnaire raisonnée d'Architecture française, Tome 3, p. 248, Cimetière.)

†On Fig. 1, plan of the ground floor—*a* represents the entrance to the light-house; *b*, the hall; *c*, store-room; *d*, kitchen; *e*, office; *f f*, keeper's rooms; *g*, wood-house; *h*, blacksmith shop; *i*, workmen's room; *j j*, spare rooms. Fig. 2 represents a plan of first story; Fig. 3, plan of second story; Fig. 4, plan of third story; Fig. 5, plan of service room; Fig. 6, plan of lantern room.

could be reached. A circular chapel occupied the next floor above; it was lighted by two rows of windows, covered by a spherically arched ceiling, and ornamented with Corinthian pilasters and handsome carved work. The bust of Louis de Fois. the celebrated architect of this monument was placed over the door of the chapel, and the following inscription in a large frame above it:

QVAND IADMIRE RAVI CEST ŒVVRE EN MON COVRAGE
MON DE FOIX MON ESPRIT EST EN ETONNEMENT
PORTE DANS LES PENSERS DE MON ENTENDEMENT
LE GENTIL INGENIEVX DE CE SVPERBE OVVRAGE
LA IL DISCOVRT EN LVY ET DVN MVET LANGAGE
TE VA LOVANT SVBTIL EN CE POINT MESMEMENT
QVE TV BRIDES LES FLOTS DV GRONDEVX ELEMENT
ET DV MVTIN NEPTVN LA TEMPESTE ET LORAGE
O TROIS ET QVATRE FOIS BIEN HEVREVX TON ESPRIT
DE CE QVAV FRONT DRESSE CE PHARE IL ENTREPRIT
POVR SE PERPETVER DANS LHEVREVSE MEMOIRE
TV TES AQVIS PAR LA VN HONNEVR INFINI
QVI NE FINIRA POINT QVE CE PHARE DE GLOIRE
LE MONDE FINISSANT NE SE RENDE FINY.

All these parts of the primitive structure still remain, and have not been much altered by the renovations which have from time to time been made; but such is not the case with the upper part of the edifice; *it* was entirely changed when the height of the tower was increased

Above the second gallery the dome of the chapel was shown on the outside, and provided with richly ornamented dormer windows, which formed a second row of windows to this room. It was surmounted by a circular pavilion arched and decorated with composite pilasters, the entablature of which was crowned by the open balustrade of an exterior gallery leading into the lantern. This lantern, which was quite small, was built of cut stone, and consisted of eight arches, the piers of which were ornamented with columns, and the roof terminated in a chimney designed to carry off the smoke from the fire.

Under Louis XV. in 1727, an iron lantern was substituted for the masonry one, the stones of the latter having become charred by the fire, and, besides, its wide piers had the great disadvantage of obstructing a large portion of the light; but the same height was maintained, which was only about 37 meters above the level of high tide.

As this elevation did not enable mariners to see the light at a very great distance, an increase in the height of the tower was decided on. This operation, by no means an easy one, was executed toward the end of the last century, with rare skill. by Teulère, engineer-in-chief of the district of Bordeaux, to whom, as has already been stated, is due the credit of the invention of parabolic reflectors. The height of the tower was thus increased to 60 meters above high tide, giving thereby a considerable increase in its range; but it must be confessed that in an architectural point of view, the structure was far from being improved. The absence of ornament in the part of modern construction, gives it a plainness which painfully contrasts with the elegance and richness, too great perhaps, of the work of the Renaissance. The new work was not nearly as costly as the old; nevertheless, the first impression the edifice makes leaves no room for regret. One is filled with profound admiration on finding himself in the presence of this majestic monument, rising with such boldness from the bosom of the sea.

A complete renovation of this light-house was made some years ago. The object was to replace the many stones worn by time, especially on the outside, and to recut the carvings, which had worn away to such an extent, that they could scarcely be seen. Besides that, all the apartments which had at various periods been built against the rampart of the platform, to supply the insufficiency of those in the tower, were rebuilt.

Such richness of ornamentation is no longer employed in our light-houses. They are not works of luxury; they are structures of public utility, and it is better to preserve in them this character, with all possible simplicity, as they are generally located far from the centers of population.

Modern light-houses.

We have said in effect, that the most important light-houses are placed upon the most salient points of the coast. Now, these advanced headlands are generally the ends of lines of ridges which separate adjacent valleys far away from the mouths of rivers, with no fertile plains near by, and few facilities for opening roads of communication; in a word, there is nothing to attract a large number of people. Nearly all first-order light houses are thus constructed at a distance from cities, sometimes on islands or even upon isolated rocks in the sea, while the majority of our seaport towns have only small towers placed on the ends of piers. The only exception to this rule is in the cases where the coast for a long distance forms a continuous straight line; seaports then become prominent points to be marked. Thus of the forty-four first-order light-houses either finished or in process of construction on the coasts of France, including Corsica, there are only two located in cities, those of Dunkerque and Calais.

More importance is now attached to the material essentials of an edifice. The good and true should be followed before all else, and the rule is to conform strictly to the requirements of true economy, which admits everything that is useful, only rejects what is superfluous, and manages resources in order to increase the number of its benefits A judicious distribution, well designed forms, great stability and perfect execution, are the fundamental conditions. It would be a great mistake, however, not to give some attention to the beauty of the edifices which, on account of their solidity, their isolation, and the durability that assures the permanence of their utility, are called upon to transmit to future centuries the memory of their builders; but, in place of ornamentation, attention should be given to convenience of general arrangements, of harmony of proportions, and of that monumental character which comports with boldness of construction.

The principal structural features to be considered in a light-house are the tower and its stairway, the room for the illuminating apparatus, store-rooms, lodgings of the keepers and the apartments reserved for the engineers charged with their inspection and superintendence, the requisites for which will be examined in succession.

Towers and stairways.

The height that should be given to a light-house tower depends on the range (portée) or power of the light and the elevation of the site above the level of the sea; but it is not regulated alone by these two conditions. Thus, as we have said before, the question of cost is to be taken into consideration, and when a light-house of the first order is to be established upon a low site, it may happen that such a height must be given to it in order that the rays from the focus may meet the sea-horizon or reach the deck of a vessel within the limit of its range, the cost of construction would be out of all proportion to the advantages to be gained. There is, therefore, no absolute rule to be followed. It is necessary in each particular case to decide according to circumstances; that is to say, after having determined at what point it is important to maritime interests that the light should be established so as to be seen from the deck of a vessel at a great distance, and what expense the various heights would entail. Thus we see that the greater number of light-houses built on rocks that are sometimes submerged do not have the focus of the illuminating apparatus as high as those of the same order established on the mainland.

When the site is very high it is only necessary to give to the tower such elevation as will secure the lantern-glass f·om damage by evil-disposed persons, and from the striking of pebbles that are blown by the wind in hurricanes The height of the upper platform of the tower has, therefore, been fixed at about 12 meters, but that is not always sufficient. For instance, the panes of glass of the light-house at Fécamp are often injured by small pebbles that are detached from the cliff by gusts of wind, though it is 17 meters above the level of the ground. It may sometimes be necessary to give a tower a greater height than the range of the light would require in order that the structure may serve as a day-mark.

Light-house towers are nearly always cylindrical inside, and except for some harbor lights, (feux de port,) their diameter is at least equal to that of the lantern. It is never less than 3.50 meters for the first, 3 meters for the second 2.50 meters for the third, and 1.40 meters for the fourth orders, and generally it exceeds these limits. In tne light-house at Calais it is 3.70 meters, and it is still greater where the keeper's lodgings are established in the interior of the tower. The interior diameter of the light-house of Cape La Hague is 4 meters, and that of Heaux de Bréhat 4.20 meters, both of which are of the first order, and are provided with lodgings inside the tower. It was necessary to retain 3.50 meters in the third-order light-houses of Barges d'Olonne and of the North Baleines, which are in the same category.

On the outside the towers are built square, circular, or octagonal in plan, according to circumstances For light houses exposed to the action of the sea the circular form is evidently preferable to all others; it is, in fact, the only one to be thought of. It is recommended also for towers of great height, because it offers less resistance to the wind; but it is not exclusively used in this case, the octagonal form is frequently resorted to The latter, in fact, is almost as secure against the action of the wind, and has the advantage of being somewhat less expensive on account of its plane surfaces, which can be disposed better with reference to the keeper's dwelling, which is sometimes established at the foot of the tower, and of presenting in fact a more elegant appearance on account of the arrises which divide the tower, like the fluting on columns The square form is most used for towers of slight elevation, especially when they are attached to keeper's dwellings and out-houses.

When towers are established on sites so low that they are washed by the sea, they are built of solid masonry to a certain height above the level of the water, and present on the outside a concave profile on the lower part, so as to give them more stability and offer less resistance to the waves.

Whatever may be its general arrangement, a light-house tower is always terminated above in a platform, which is inclosed by a balustrade, in the middle of which is placed a cylindrical sub-base for the lantern. Against the interior wall of the base the uprights of the lantern have for some years been fastened; they were formerly bedded in the wall, as will be seen further on.

The balustrade is generally established on corbelling upon the cornice which crowns the tower. It is made of galvanized iron, or better yet, of bronze, when the space is very contracted; preference is given to stone or brick, when either can be used without reducing too much the width of the gallery, because the balustrade then becomes more apparent, adds to the general character of the edifice, and costs much less than bronze. The balustrades thus constructed are formed of slabs, full or hollowed out, which are held laterally by stone posts firmly fastened to the platform by bronze dowels. The light-houses of Bréhat, Calais, Baleines, and Haut Banc du Nord (Plates 20, 21, 22, 23, and 25) are examples of this mode of construction.

Very high towers are provided in their upper part, immediately under the base of the lantern, with a room called the *service-room*, in which one of the keepers who is not on watch sleeps during the night There are occasions when it is necessary to have two keepers on hand in the watch-room; valuable time might be lost if one of them had to come from his rooms below to answer the call of his colleague. This room serves also as a place for storing

various articles pertaining to the light. There is one in nearly all the structures represented on our plates.

Light-houses the lights of which it is not necessary to watch during the entire night, and such are those of the fourth order, have no watch-room.

When the foot of the light-house is washed by the sea, the keeper's lodgings and store-rooms are all placed in the tower, one over another. When the thickness of the wall permits, the staircase is partly built into it and partly projects into the rooms, which are then independent of each other, as is shown on the drawings of Heaux de Bréhat, (Plate 20.) When this arrangement is not admissible, narrow iron stairways are made use of to pass from one room to another. This expedient has been resorted to in several light-houses of the third order, and among others for that of the Haut Banc du Nord, which is represented on Plate 25. In this case the stairway opening in each chamber is covered in by a frame mantel built around it.

Some light-houses are built on isolated rocks, the tops of which the sea never reaches, and consist only of the tower without attached dwellings, because of the limited extent of available surface. Their stairways are established sometimes in a turret built up against the main tower, as in the light-house of Triagoz, Plate 27, or in a cylindrical opening in the mass of masonry, conforming to the arrangements shown on Plate 28, of the light-house of Kermorvan.

In light-houses built on the mainland a circular stairway generally occupies the greater part of the interior space of the tower.

These stairs had formerly a solid newel; their treads were fastened on one side into the walls of the tower, and on the other in the central newel. More recently, and for towers of large diameter, a string-wall, forming a kind of hollow shaft in the middle of the structure, has been used instead of the newel. At the present time all these staircases are open, except those of small light-towers, the dimensions of which do not permit an arrangement of this kind. These open stair-ways have over all others the advantage of being much more elegant, and of allowing oral and visual communication from one point to another. They do not always have their starting point at the foot of the tower. A vestibule is sometimes established there, and the stairway commences at the story immediately above, as is shown in the plan and section of the light-house at Calais, (Plate 21.) A staircase of this kind would occupy too much space in the service-room if it were carried up through it. It is generally stopped somewhat below the floor of this room, (2.5 or 3 meters,) and is prolonged by means of a small cast-iron stairway, which is narrower and steeper. Another cast-iron stairway similarly arranged leads from the service-room to the lantern. The landings of these stairs in each room are ceiled up by means of a cylindrical mantel, (tambour en menuiserie.)

Openings are cut in the arches for the passage of the stairs, and in order to reduce the dimensions of these openings as much as possible they are bounded on the sides by cylindrical surfaces, and above and below by parallel helicoidal surfaces, having the pitch of the stair-way, and separated by a vertical distance of about 2.25 meters for head room. Plates 20, 26, and 27 give examples of this arrangement, and one of them is represented in detail by Figures 5, 6, 7, and 8 of Plate 22.

When a tower is required to be very high it is necessary to take into account a matter which is rarely considered in architectural studies. We refer to the action of the wind, which may cause too great vibrations, and might even overturn the structure.

These vibrations have been observed in the greater number of our light-houses which exceed 40 meters in height, and they are manifest frequently in constructions of less height; they cause a liquid contained in a vessel to spill, or the weights of the clock-machinery of the lens-apparatus to strike against the walls of the well, and produce upon some persons an effect analogous to that produced by the rolling of a ship. These vibrations are due to the elasticity of the masonry, and up to the present time it is not believed that they are of such a nature as to injure the solidity and the durability of the structure, when maintained within the limits,

assured by the thickness given to the masonry of our light-houses. No splintering of the edges of the stone, nor opening of joints, nor cracking of stucco upon the surfaces covered with it have been noticed which can be attributed to these vibrations. They do not indicate a tendency to overturning. The tower should be considered as an elastic shaft, solicited to flexure by the intermittent action of the wind.

In order to determine the amplitude of oscillations of this kind to which a structure might be subjected without danger to its stability, would require observations which have never yet been made, and to make which would present great difficulties. Nor does it appear that there would be any real utility in submitting the question to a rigorous calculation, since experience proves that the vibrations in question cause no damage to light-houses which have the excess of stability that it is customary to give to edifices of this kind.

This last question has been treated by M. Léonor Fresnel in a memoir on the Belle Isle light-house which was published in the Annals des Ponts et Chaussées. We will not undertake to present an analysis of this work. It will suffice to state that it is not prudent to give to a light-house tower less than five times the stability that would be rigorously necessary to maintain its equilibrium under the force of a hurricane capable of exerting a pressure of 275 kilogrammes per square meter (56 pounds per square foot) on a plane surface normal to the direction of the wind, and supposing that rupture tends to take place along a horizontal section.

Apparatus-room.

The apparatus-room is composed, in the majority of our light-houses, of a sub-base or parapet of masonry surmounted by a lantern. The uprights of this lantern were formerly set in the upper courses. Now, in the light-houses of the three principal orders, they are set against the interior wall of the parapet, and are bedded into it their entire thickness. This arrangement has the advantage of allowing them to be easily placed, of giving more space in the lower part of the apparatus-room without increasing the diameter of the lantern, and, lastly, of affording the keepers a somewhat wider platform to stand on when cleaning the exterior of the lantern-panes. Lights of the fourth order, which have small towers generally placed on piers, neither require nor admit of this modification to the lantern.

It is necessary to guard against strong currents of air, which would cause the light to flicker and smoke, and against the entry of dust, which would tarnish the apparatus and even in time impair its polish. This is accomplished by covering the head of the stairway giving access to the room, and the door cut in the parapet leading out on the exterior gallery, with a *tambour en menuiserie*, forming a kind of air-lock. This door is generally placed upon the upper landing of the stairway, as shown on the majority of the plates representing light-houses.

This *tambour* is generally built up to the bottom of what is known as the interior service gallery A large closet, which is comprised between this gallery and a slanting roof, is established over the stairs. The door of this closet opens in the opposite direction from the entrance-door.

In order to prevent as far as practicable the accumulation of dust in the apparatus-room, and enable the keepers to keep in a proper state of cleanliness the apparatus itself, the floor and inside of the walls of the parapet are built of hard marble. The parapet is not then a cylinder on the interior, but a right prism with a polygonal base, and has the same number of sides as the lantern itself.

The floor of the lantern-room is supported by an arch in light-houses of the first three orders. This arch is generally built of brick; but the keystone is a cut-stone of sufficient dimensions to allow the insertion of the foot of the cast-iron pedestal on which the apparatus rests. The thickness of this keystone is generally fixed at about 0.40 of a meter, and the thrust is taken up in some cases by means of bronze cramps, and in others by an iron ring bedded in the masonry.

In light-houses of the fourth order the parapet is cylindrical, both on the inside and outside; the floor is formed by the last step of the stairway, and there is no air-lock.

The lantern-parapets are always built of cut-stone.

When a light does not illumine the entire horizon, the top step of the service-gallery stairway is placed in such a manner that it comes into the dead angle of the apparatus, and the same arrangement is adopted for the stairs of smaller towers, in order that the keeper may not mask the light in attending it.

The following table gives the dimensions now in general use for the various parts of the lantern-rooms of different orders of lights:

| Order. | Diameter of the parapet. | | Number of sides of the polygon. | Height of the parapet above the floor of the lantern-room. | Diameters of the openings to be left in the center of each arch. |
|---|---|---|---|---|---|
| | Exterior. | Interior. | | | |
| | *Meters.* | *Meters.* | | *Meters.* | *Meters.* |
| 1st | 4.40 | 3.50 | 16 | 2.00 | 0.36 |
| 2d | 3.80 | 3.00 | 12 | 2.00 | 0.31 |
| 3d | 3.20 | 2.50 | 10 | 2.00 | 0.26 |
| 4th | 2.00 | 1.40 | 10 | 0.90 | 0.26 |

At places where the winters are very severe, a small heating-stove is sometimes placed in the lantern-room, or, what is preferable, in the service-room when there is one.

Store-rooms.

A good arrangement of store-rooms is of the greatest importance for regularity of attendance and the preservation of supplies. In light houses of the third or lower order, a single room is often devoted to this use; there are generally two in light-houses of the two higher orders, and one of them is exclusively devoted to the storage of oil, which is contained in oaken tanks lined with tin. The oil-room ought to be, as much as possible protected from the variations of the outside temperature without being in a dark place. It is well that the room containing the wicks, the chimneys, the spare parts and the various utensils should be provided with glazed closets, in which all these articles can be arranged methodically, and protected from moisture and dust. A covered communication between the light-house and the store-rooms is regarded as essential to good service.

The store-rooms of the Baleines light-station have been very conveniently arranged. The oil-room is in the basement, as will be seen by reference to the drawings, (Plate 22,) and access to it is had from the outside; the other store-room is placed above. Both are in direct communication with the stairway of the tower.

In light-houses isolated in the sea the store-rooms are necessarily of very limited dimensions sometimes all the supplies are stored away in a single small room. The light-house of Cordouan is an exception in this respect, as it is in many others.

Keepers' dwellings.

Light houses attended by a single keeper are generally placed in charge of married men, who are, with their families, quartered at the station. This arrangement has the advantage not only of making it more comfortable for the keeper himself, but it insures the supplying of his place temporarily in case of necessity, as the duty is so light that it can be temporarily performed by a woman or even a child.

The dwelling consists of one or two rooms with a fire-place, an attic, and sometimes a cellar. A yard and a small garden are generally connected with it. At some of these stations the keeper's house is placed in such a position with reference to the tower that the light can be seen from one of the windows; in most cases the house is connected with the tower in such a manner that if the keeper be obliged to get up during the night to trim the lamp, he will at least not be compelled to expose himself, on getting up from his bed, to the severity of bad weather.

In light-houses of the first three orders provided with lenticular apparatus, the light of which has to be watched during the entire night, it is necessary to have several keepers, who take the watch by turns, and the question of the propriety of providing quarters for their families, where circumstances permit it, is one that has more than once been discussed and in different ways settled.

This plan was adopted in most of our old light-houses, and it was not found to work well The light-stations were deficient in respect to order and cleanliness, and the almost inevitable dissensions, when the inmates are numerous and not accustomed to discipline, prevent the keepers from preserving at all times among themselves that good feeling which is necessary to the efficiency of the service. In consequence, it was decided only to admit the keepers themselves *in the light-houses*, leaving to those who were married the care of quartering their families as they deem proper. The lodgings then are composed of a single room for each keeper, and a common kitchen. The Corsican light-house of Porto Vecchio is arranged in this manner, the designs of which are given on Plate 24.* The desired result was thus obtained, but grave disadvantages very soon demanded some other arrangement.

To separate the keepers from their families was in effect, to increase the expenses of men whose pay was already small; to deprive them, without sufficient necessity, of those home enjoyments to which the duties and cares of paternity legitimately entitle them; to add to the discomforts of their isolation in rendering it more painful and complete; and finally, to expose them most strongly to the temptation of absenting themselves from the light-house at the very time when their presence is most necessary.

The system now adopted consists in disposing the quarters in such a manner that they may be independent, and may be completely outside of the edifice which is devoted to the public service. They may be attached to the light-house, and often are, but they have separate entrances; each of them is connected with a small yard, and they are located in such a manner as not to injure the general appearance of the station. They are required to be kept in a very neat condition, and dissensions are repressed when they are of sufficiently grave a nature to be taken notice of by the person charged with their superintendence. These dissensions are much more rare than formerly, thanks to the arrangements which render their intercourse less constant, and enable each family to isolate itself as much as it pleases.

The quarters of each keeper are generally composed of two rooms with a fireplace in each, and one or two closets. One or more rooms, according to circumstances, are reserved for the engineers and assistant engineers charged with the supervision of the light-house.

The light-house of Baleines, which is represented on Plates 22 and 23, is given as an example of these arrangements. Each set of apartments for the keepers is composed of a room on the ground floor, and another on the first story above, each having a small room or closet attached, and has two entrances, one on the front of the edifice the other on the rear. They are marked on the plan by the letter *d*. The spare rooms consist of a room on the ground floor, and another above with a closet attached.

The keepers' apartments of La Hève light-station are located in a detached building, situated between the two towers, as shown on Plate 19. At the new light-house at the Isle d'Oues-ant the quarters are also located in separate buildings, but a gallery or covered way places them in communication with the tower.

Figure 5 of Plate 24 represents the plan of the ground floor of this station: *a*, represents the entrance to the light-house; *b*, the gallery or covered way; *c*, the store-room; *d*, the keepers' apartments; *e*, the spare-room.

The light-houses of Ailly and Barfleur have the quarters constructed upon the sides of a yard, in the center of which is the tower. At Hourtin and at Contis the quarters are placed behind the towers and each has a separate yard.

The families of light-keepers ought not to be allowed at light-stations isolated in the sea, which are only composed of a tower; but there are some places where they have quarters on the main-land, near the port from which communication is had with the light-house.

* Figure 3: *a*, vestibule; *b*, the light-house stairway; *c*, kitchen; *d d*, keepers' rooms; *e*, spare room; *f*, store-room.

Sometimes there is difficulty experienced in keeping the interior of light-houses free from moisture; the mortar used in construction may have been made with sand from the sea-shore, or perhaps the stones or the joints may allow rain to drive through them. Pointing, painting in oil, and the various mastic coatings are generally poor palliatives. The only means that has been found to be universally successful, consists in building on the interior a separate brick partition a few inches from the exterior wall. It has been tried under various circumstances, and among others, to the keepers' dwellings at the Cordouan light-house, as is shown on Plates 16 and 17.

Whenever local circumstances permit, each keeper is allowed a small piece of ground to cultivate as he sees fit. This gives a useful and agreeable occupation to their spare time. These gardens are generally within an inclosed space which surrounds the station.

Situation.

The matter of facing the buildings in the proper direction is one of considerable importance, as nothing exercises so much influence on the welfare of their occupants and the preservation of the work. It is essential that the principal openings should be opposite the side that is exposed to the prevailing winds, that the rooms may have the benefit of the light and healthful influence of the sun's rays. The best directions to face a building in our country, are between the south and the east.

It may be remarked that plans similar to those of the Porto Vecchio station cannot be made to satisfy this condition.

Frame light-houses.

Sometimes the illuminating apparatus is established on an open frame-work, of wood, either because the light is to answer a temporary purpose or because it is to mark changing channels or bars, and consequently subject to removal at more or less frequent intervals. Plate 29 gives an example of one of these constructions, which will be again referred to further on. The keepers in such a case are quartered in a house especially constructed for the purpose in the vicinity of the light-house.

Iron light-houses.

For light-houses iron is not as good a building material as stone; it has less durability, costs more to keep it in repair, and does not stand so well the thermometric variations of the atmosphere. There are circumstances, however, when it is necessary to have recourse to it, and it has thus given rise to several systems of construction.

One of them, invented by Mr. Mitchell, a very distinguished engineer, who, as well as his worthy associate, Mr. Saunders, met with a premature death, has been frequently used in England, and has been adopted in France for a light-house recently constructed north of Calais, upon a sand-bar which is bare at the lowest spring tides It consists of wrought-iron piles, which are provided with cast-iron screws on their lower ends, maintained in place by ties and braces, and surmounted, at a safe distance above the level of the highest tides, by a platform upon which is established the keeper's dwelling. The lantern is set on top of the iron frame-work of the house. Plate 31 represents the French light-house of this character, a further description of which will be given.

A different arrangement is applied to iron light-houses the bases of which are not submerged. It consists of sheets of boiler-iron bolted or riveted together, and sometimes held by a frame made of flat or T-irons. It is especially adapted to light-houses to be built in colonies, where there are no facilities for construction; upon rocks that are difficult to reach; or upon piers the top surfaces of which is so contracted that it is of the greatest importance to economize space. Some examples of this mode of construction, which have been executed of late years, will be given.

Some harbor-lights have been established upon cast or wrought-iron posts, with a small room at the bottom made of boiler plate-iron, which is used as a lighting-room.

Finally, in the construction of towers it has been proposed to form them of cast-iron sections, one above another, and bolted together.* Cast-iron has over wrought-iron the

* This system of construction has been used in the United States in a number of places, and has given satisfactory results.—P. C. H.

advantage of less tendency to oxidation, but it has the disadvantages of requiring greater thickness of material, is less flexible and more exposed to rupture, and it does not appear to be any more economical.

## II.—TYPES OF EDIFICES.

Several plates annexed to this memoir represent light-houses which are examples of the principal arrangements we have just described. With the exception of Cordouan, which has already been described in the first part of this chapter, it may be useful to enter into some of the details of each of them.

Light-houses of La Hève.

Cape de la Hève, near Havre, is marked by two towers with fixed lights of the first order. The buildings, which are represented on Plate 19, were constructed in 1774. Surmounted at first by grate-fires, in which coal was burned, each of them was crowned in 1781 by a lantern, which contained an illuminating apparatus formed of sixteen spherical reflectors, illuminated, some by three and others by two lamps with flat wicks. There were forty burners to each apparatus. Six of Bordier Marcet's reflectors in each light-house were substituted in 1811 and 1814 for these defective apparatus. Their number was increased to ten in 1819. Finally, the two towers were thoroughly repaired and modified in their upper parts, in order to receive lanterns 3.50 meters diameter, in which the lenticular apparatus was placed. At the same time the keepers' dwellings were established between the two towers.*

Figures 4 and 5 give the plan and elevation of the structures. Figures 1 and 2 represent, on a larger scale, an elevation and section of one of the towers. Figure 3 is a plan of the lantern-room.

Each keeper has two rooms (chambres à feu) with a fire-place in each, a small room or closet, an attic, and a wood-shed, the latter being in the yard.

The arrangement of these buildings has not been cited as a model to be followed; it was necessary to cut away the upper part of the walls in order to have room to place the new lanterns; the full-neweled stairways are not convenient for passage up and down; finally, it would have been better to have had the keepers' dwellings nearer to the light-houses. But the structures present a very fine appearance.

Unfortunately, the cliff on which these light-houses stand is continually wearing away, and it is probable that it will be necessary to rebuild them before long at some distance in rear of the positions they now occupy.

In the double light-station that was built some years ago at the mouth of the Canche, other arrangements were adopted. The keepers' dwellings are annexed to the towers in a manner similar to that shown on Plate 23, except that as there are only two keepers for each light the buildings are carried up only one story. A small building placed between the towers is used by the light-master, (*maitre de phares,*) and the engineers when on tours of inspection.

Light-house of Heaux de Bréhat.

The light-house of Heaux de Bréhat, which is represented on Plate 20, was commenced in 1836, after a season employed in preparatory work, and was finished in 1839. Although the art of building such structures in the open sea has made considerable progress since that time, it may be well to go more into details in regard to this work, in order to appreciate the difficulties of construction in works of this kind.

The light-house is situated about 5 000 meters (about 3 miles) from the most northerly end of the peninsula of Brittany, upon the plateau of Heaux de Bréhat, which consists of a porphyritic rock nearly 500 meters diameter at low tide, and at high tide, with the exception of some scattered rocky projections, entirely submerged. The tidal currents in this neighborhood are very strong; their velocity reaching eight knots per hour, (4.11 meters per second,) and in gales of wind the sea attains an extraordinary violence, the waves dashing up to a considerable height, and breaking with great force against the obstacles that they encounter.

*One of these towers has since been modified in the upper part to receive an electric-light apparatus. Since then the other has also had the electric apparatus placed in it.

The edifice does not occupy the highest point of the rock. It was much more essential to establish it near the place where landings could be made most frequently, in order to reduce as much as possible the expense and difficulties of transporting materials. This point, situated in a cove at the south edge of the plateau, offered at low tide good cover from the winds coming from sea between points of the compass included between north and west southwest. A rocky head was here found which was above the level of mean tide. It drops off vertically on the sea side, and at its foot there is always to be found, except in low spring-tides, a sufficient depth of water for vessels of small tonnage. At a short distance from this was a flat space covered in the highest tides by 4.50 meters water. This spot, all things considered, was regarded as the one that would reduce the cost to a minimum, and it was accordingly adopted for the construction.

The arrangements relative to transportation, landing, and delivery of material, is not less important to the success of enterprises of this nature than the choice of site; and the following were adopted.

The isle of Bréhat, situated about 10 kilometers (6.2 miles) from the rock, is farther off than the main land, but it has harbors with excellent anchorage ground, which can be found nowhere else upon the neighboring coast, and what is of still more importance, it is favorably located with reference to the direction of the tidal currents, the ebb-tide setting directly from the island to the rock. It was, therefore, chosen as the point of embarkation; a small dock built of stone laid dry was constructed in that one of its natural ports which afforded the best facilities, and storehouses and workshops for preparing the material were put up in close proximity thereto. All the stones used in the construction were cut at this place. In order to insure the greatest accuracy of workmanship, each entire course was laid out on a horizontal platform, resting on skids; then the stones were shipped in barges of about 40 tons burden, each carrying its number, its sling, and the straw mats necessary to prevent the edges from being chipped off.

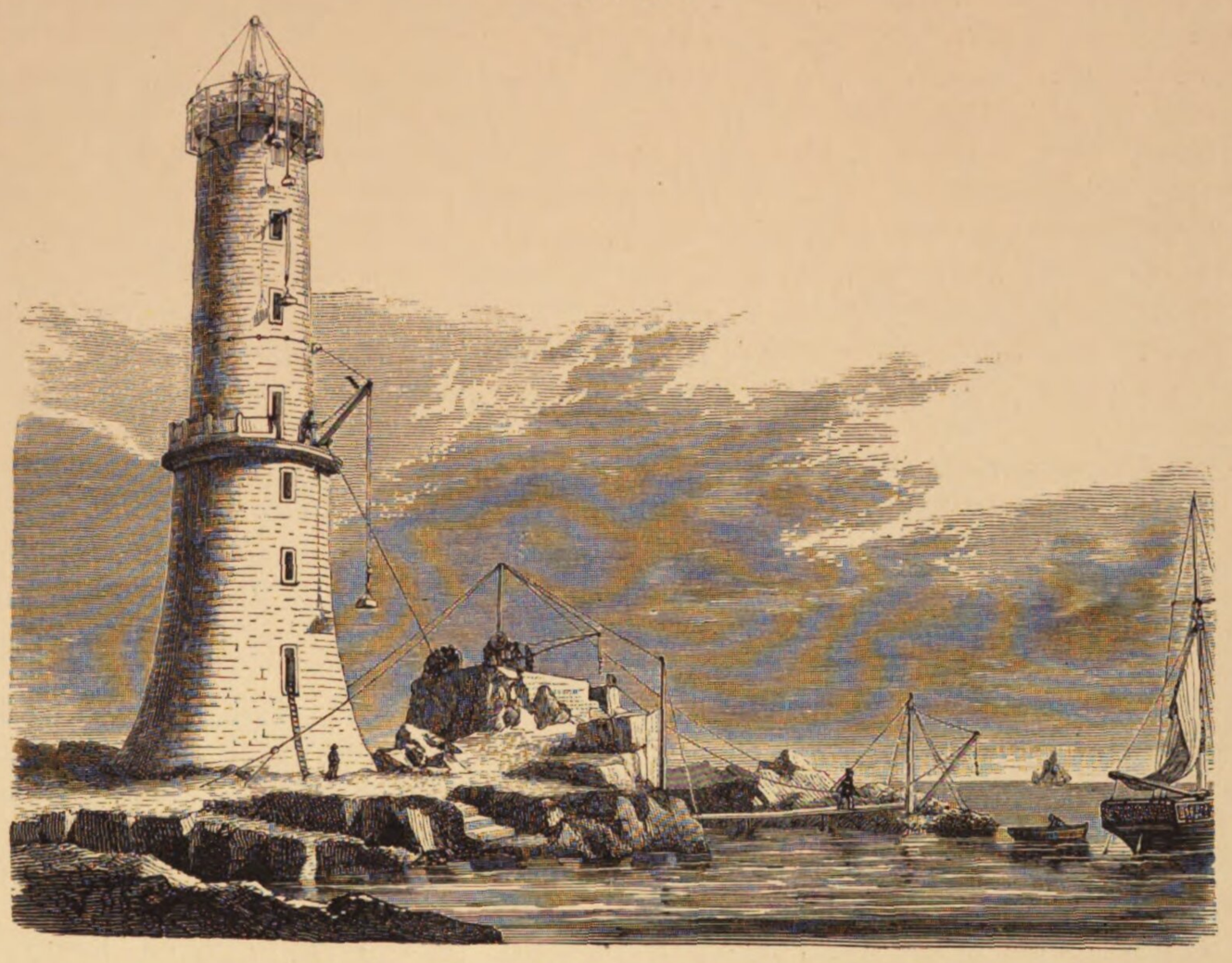
These vessels set out from the island at the commencement of ebb-tide and were laid along side the rock generally before low water. They were held in position by means of moorings, so arranged that they could cut loose promptly in case of necessity and haul off from the rocks which surrounded them. A derrick which was submerged at each tide was solidly fixed on the head of a rock, at the side where the landing of the materials took place. It consisted simply of two spars, one set vertically in the rock, the other inclined and made fast to the former at the lower end so as to swing freely around it; the top of the inclined spar or boom was manipulated by a line to the top of the vertical one, and two shrouds worked on board the vessels in such a manner that it could always be set in such a position that the stones could be taken out of the hold of the vessel quickly. The stones were only raised a short distance, and were placed on a tramway-car and carried to a place where they were handled by other derricks. The number of the latter to pass the stones from one to another was increased as the work progressed, in order to economize as much as possible the time taken in landing and delivering material.

During the construction of the solid masonry of the base, a derrick with a long boom, held in place by six guys made fast to the rock, was placed in the center of the structure, upon a timber platform resting on four posts about 3 meters above the level of the highest tides. These posts were each held by five guys fastened to two strong iron pins about 3 inches in diameter sunk in the rock. They all stood in the rubble masonry of the space corresponding to the interior hollow of the tower, so that, as the work progressed, they were enveloped and buried in it. They are represented on the plan (Figure 3, Plate 20) and section (Figure 2, same plate) by dotted lines. Afterward the same derrick was placed at the intersection of two trussed beams, which rested on the masonry of the tower, and was raised as the work was carried up, by means of screw-jacks. It took up the stones on the outside and set them exactly in place, it being easy to vary the reach of the boom, even when a large stone was hung to it.

A flying scaffold was used in the construction of the tower, which was carried up as the work progressed. It consisted of a series of small fir trestles, which were clasped against the tower by means of two chain bands, which were drawn up tight by means of jack-screws. A guard, to keep the men from falling off, formed of three lines of rope cord, was fixed upon the exterior uprights of the trestles. When the scaffold was to be raised, the screws were turned back, each trestle was seized by a man standing on the masonry of the tower, and at the word of command all raised together; the chain bands were then drawn tight again. The entire operation did not take more than a quarter of an hour. This simple and economical system of making a scaffold was employed in the construction of the Belle Isle light-house, and has been frequently used at other places since.

The sketch below will give an idea of the arrangements made for carrying on the work when the construction had been carried up to a height of about 36 meters above the rock. The sketch is taken at low tide.

FIG. 29.



It was important that the workmen should be quartered on the rock, as it was evident that their time could be usefully employed, even when tempestuous weather should interrupt communications for several days at a time. However well prepared the stones might be, they had in fact to be finished off upon the spot; each course had to be carefully leveled after having been put in place, and notwithstanding the arrangements made to assure rapidity in the landing of material, it was impossible sometimes to lay all the stones of a cargo during one low tide.

Two very slender peaks, close to each other, and located near the center of the plateau, with their summits almost 6 meters above the level of the highest tides, offered a good point on which to construct the necessary buildings for the workmen. The space between them was filled with loose stone, and the mass held together by them on the north and south, was maintained on the west by a vertical wall, and on the east by an inclined plane, both made of large blocks laid in cement. A nearly square platform was thus obtained about 9 meters

on the side, and leveled off about 4 meters above the level of high tides. A frame building well anchored, was erected on it. It contained store-rooms, a small forge, and rooms for the engineer, the foreman, and the workmen. The structure was surmounted by a small tower from which a temporary light was exhibited.

The space being very contracted, it was necessary to economize it as much as possible. In the room occupied by the workmen, a row of hammocks was hung over a row of contiguous bunks, the available space for each man being only 0.67 of a meter by 2 meters. Good ventilation, however, was maintained in this room, though it was only 2.70 meters by 10 meters and held thirty-nine men. Other hammocks were hung at night in all the rooms where it was possible.

From this temporary building there issued daily about sixty men, to go to work on the rock immediately after the sea uncovered it, and that was their only refuge after the return of the tide.

Measures had been taken to have the quarters kept in the highest state of cleanliness, and the men well fed. Thus, the health of the workmen was always good, though they only went ashore once a month, and then only for a day.

The light-house consists of a tower with an interior cylindrical opening 4.20 meters in diameter, and 47.40 meters high from the base to the foot of the lantern. It consists of two principal parts. The lower is trumpet-shaped at the base, and is built of solid masonry to a height of one meter above the level of the highest tides. The pressure that it sustains, as well as the shocks to which it is exposed, rendered it necessary to give it great solidity; the interior diameter was accordingly fixed at 13.70 meters; that of the top, 8.60 meters. The second, considered as standing on an immovable base, has a degree of lightness about the same as that usually given to a tower of the same height built on the shore. The thickness of the wall is 1.30 meters at the bottom, and decreases to 0.85 of a meter immediately under the cornice.

The concave profile of the base, which would give the greatest stability, could not be deduced from any formal law; but it should evidently be tangent to a nearly vertical straight line at its upper extremity, and present a degree of curvature increasing from the top to the bottom. These conditions are satisfied by means of an arc of the elipse. The tangent at the summit being given, the direction of the tangent at the base is settled upon after some trials, and from them the equation of the curve is deduced.

The interior of the edifice is divided into several stories. The first two are used as store-rooms and advantage is taken of the thickness of the walls to form four large niches which serve for closets; the four above are used as a kitchen (Figure 5) and keepers' rooms; the seventh is a room fitted up in somewhat better style than the others, designed for the engineers; the service or watch-room is on the eighth floor, and above that is the lantern-room, (Figure 6.)

The entrance door of the tower opens to the south, (the prevailing winds being from the north,) and at one meter above the line of the highest tides; it is reached by means of a ladder made of bell-metal, set in a recess of the tower-wall. Opposite this door, (Figure 4,) and beyond a small vestibule is a stairway, the lower part straight, the upper part circular, with full newel, by which communication is had with the different stories; it is carried up to the line of the service chamber. The casing of this stairway is built in the tower-wall on one side, and forms on the other, upon the cylindrical opening of the tower, a projection the recesses on each side of which are utilized by forming closets.

The entire work is built of perfectly homogeneous granite, of fine close grain, and a bluish tint. The arches are built of brick made according to pattern, with the exception of that which supports the floor of the service chamber; this was built of concrete, because the bricks did not arrive in time.

The porphyritic rock upon which the structure rests is of extreme hardness and rapidly wears out the best-steeled tools; but in some places it has many fissures, from which the sea

breaks off small fragments. This state of things prevented the establishment of the foundation on the same level throughout its entire extent; it was necessary to divide it in several parts, so as to avoid any chance of its being entirely swept away, and at the same time not to add too greatly to the expense of excavation. In the center, a circular space 4.20 meters diameter, corresponding to the interior hollow of the tower, required and received no preparation. Outside of that, an annular space 11.70 meters exterior diameter was leveled off to 0.15 of a meter below the lowest point of this part of the plateau; then there was hollowed out at the circumference a trench one meter in width, with a depth which varied with the condition of the rock, in such a manner that no part of the base of the structure should be protected by less than 0.40 of a meter height of compact porphyry. At four places where the rock appeared susceptible of injury, to a considerable depth it was necessary to cut down the defective part and go beyond the limits of the foundation, to obtain lateral support on the solid porphyry; the cavities thus formed outside were afterward filled with concrete.

In works of this kind, it is necessary to have all the stones joined solidly to each other, in order that the sea may not move them either during or after the execution of the work. This effect is especially to be guarded against in the former period, when the masonry is covered at times by the sea and the mortar has not attained the proper degree of hardness. Some very expensive means have been at times adopted to provide against this contingency. Thus in the light-houses of the Eddystone in England, and of the Bell Rock in Scotland, all the stones in the lower courses were bonded together in a very complicated manner, and were held in place by great numbers of iron or wooden dowels These arrangements are not without advantages, but it is very doubtful whether they are absolutely necessary. They may even be a source of great inconvenience, as outside of the expense which they entail, they sadly retard the execution of the work, which it is of great importance to raise above the level of the sea as soon as possible. However that may be, it was not deemed necessary to have recourse to such a system in the execution of the light-house of Bréhat, and it was proposed, as a necessary condition of problem, that the end should be attained as economically as possible; in other words, it was determined to risk all the damages that it appeared more difficult to prevent than to repair.

It was therefore decided not to fasten each stone separately, but to limit ourselves to placing the quantity of masonry which could be put in solidly during one low tide. Each course was divided into a certain number of large sections or keys, each of which was connected in the lower part of the construction by means of four small granite blocks, fitted in each course and placed in the angles of the section. The angular stones belonging to the exterior facing, being thus kept in place and forming tie-pieces, support the facing-stones which come between them, as is shown by Figure 3, and are attached to those which compose the sides of the key by means of dovetails let in their whole thickness. Finally, the interior face, maintained upon the preceding course by two stones, is also held by the stone belonging to the course above, which, being placed across the joint, allows the tie-pieces on that side to be suppressed. The perimeter being made firm, artifices of construction are not required for the interior, and in the first courses, which it was necessary to finish rapidly, and where there was considerable surface, it was finished in rubble masonry.

Experience justified these arrangements. No damage was sustained whenever an entire section could be placed before the return of the tide, which was generally accomplished; it was the same even when the work had to be discontinued, without having placed any other stones than those of the facing, from which the work always commenced; but sometimes they were not prepared in time, and some stones were raised and moved a short distance out of place. The operation was positively advantageous, both as to economy and rapidity of execution.

Constructions in the water are carried on at the present day under much more favorable conditions. In the first place, thanks to the aid of steamboats, the service of transports is much more certain, and neither calms nor contrary winds interrupt the work. In the second

place, Portland cement is a great advantage. It sets more slowly than other cement-mortars, but more rapidly than any lime-mortar, and has over all mortars the advantage of greater hardness and strength, which enables us to dispense with complicated systems of bonding. With it, works can now be executed entirely in rubble masonry, and there are circumstances when this plan could be adopted with great advantage, it being only necessary to point the masonry with a quick-setting cement a little before the tide rises and covers it.

Beacon towers, intended to mark some of the submarine dangers on our coast, are nearly always constructed at the present time of small stones; this system was adopted for the Grand Lejon beacon, at the entrance of the bay of Saint Brieue. It has been built sufficiently large to allow of its being at some future time converted into a light-house if necessary.

Undoubtedly, a work constructed in this manner has not the same degree of durability as those built principally of large cut-stone of good quality, and it is by no means yet an established fact that Portland cement, which does not, as far as we know at present, decompose when exposed to sea-water, will resist this action forever. But it is not a matter that need be considered with reference to the interior masonry of a work; the evil, if produced, will manifest itself first on the outside in such a manner that remedies can always be applied.

The actual cost of constructing the light-house of Bréhat was 531 679 francs, (about $106 335,) exclusive of the lantern and illuminating apparatus.

Light-house of Calais.

Plate 21 gives the plan, section, and elevation of the light-house (1st order) at Calais. Figure 1 represents the front elevation; Figure 2, a section through the axis of the tower; Figure 3, a sectional plan taken through the line A B; Figure 4, a sectional plan through the line C D; Figure 5, the plan of the watch-room.

This edifice, situated in a city, at the end of one of the streets, it was thought advisable to finish in a more handsome style than light-houses generally are; the use of cut-stone was restricted to certain parts only, on account of its high price in this locality, and the greater portion is therefore executed in brick.

The tower is octagonal in plan, and is united to the main building, two stories in height, designed for keepers' apartments and store-rooms. The base or plinth is built of cut-stone, as are also the framing of the window openings, the pilasters, the cornice and the balustrade of the crowning, and the lantern parapet; all the rest of the walls are built of brick masonry.

The foundation consists of a mass of béton, comprised in a space inclosed with sheet-piling. It rests on a stratum of sand.

The edifice was commenced in 1845 and completed in 1848.

The cost of the work, not including the lantern and illuminating apparatus, was 186 980 francs, (about $37 396.)

The greater portion of the work was executed under the superintendence of M. Werner, a young engineer of distinction, who died some months afterward. The work was finished by Engineers MM. Charié and Leblanc.

Light-house of Baleines.

The light-house of Baleines (1st order) is situated at the northern extremity of the isle of Ré. It is shown on Plates 22 and 23. Plate 22, Figure 1, is a section through the entrance doorway and the axis of the tower; Figures 2, 3, and 4 are sectional plans taken on the lines A B, C D, and E F respectively; Figures 5 and 6, the inverted plan and elevation of the opening left in the upper arch for the cast-iron stairway; Figures 7 and 8 represent developments of the lateral faces of this opening. Plate 23, Figure 1, is a plan of the ground floor: *a* is the vestibule, *b* the store-room, *c* the hall, *d d* keepers' apartments. Figure 2 is the front elevation of the tower and buildings.

The foundation of this edifice presented no difficulties; it rests on a limestone rock which is found at a slight depth below the surface. It was not established on a level bed on account of the inequalities of the surface of the rock, and the necessity of having a cistern built below the store-rooms.

The base and plinth of the tower and buildings, the corner quoins, the coping, the cornice, the balustrade, and the steps were built of Kersanton blue granite, the best and most beautiful material for construction that can be found on the peninsula of Brittany, which is rich in valuable building-stone. The remainder of the edifice is built of limestone, quarried on the banks of the Charente.

The cost of this work, including the wall inclosing the light-house grounds, and other contingent expenses. was 281 226 francs. The work was commenced in 1849 and was finished in 1853. It was carried on by Engineer M. Legros, under the successive direction of MM. Job de Soulangy and Leclerc, engineers in chief.

Light-house of Porto Vecchio.

The light-house of Porto Vecchio, (1st order,) which is represented on Figures 1, 2, 3, and 4 of Plate 24, may be considered as a type of the arrangements adopted for light-houses of slight elevation, with keepers' lodgings attached, but in which the keepers are not allowed to bring their families. On one side of the vestibule *a* (Figure 3) is the kitchen *c*, on the other the spare-room *e*; the store-room is marked *f*, and the letter *d* indicates the keepers' apartments. The plan of the lantern-room is given on Figure 4.

The edifice is executed entirely in cut-granite, the foundation resting on the rock.

The cost of construction was 63 051 francs.

Light-house of Pointe de Grave.

The light-house tower at the Pointe de Grave (3d order) is square in plan, and is partly inclosed in the main building, which contains two sets of keepers' quarters and the light-house store-room. It has a garden in front and an inclosed court in the rear, with sheds and outbuildings.

This edifice is represented on Plate 26.

Figure 1 is a front elevation.

Figure 2 is a section through the front door and axis of the tower.

Figure 3 is a plan of the ground floor: *a*, tower; *b*, store-room; *c*, *c*, keepers' quarters.

Figure 4 is a sectional plan of the watch-room taken at C D.

Figure 5 is a sectional plan through E F of the lantern-room.

The structure is built of rubble masonry covered with stucco; the plinth, the cornice, and openings are built of cut-stone, the corners of the building and tower having quoins of the same material. The foundation is built on sand, and consists of a mass of béton held in a pit revetted with piles and sheet-piling.

The cost of the work was 68 710 francs. It was executed under the supervision of Engineers MM. Droëling and Robaglia.

Light-house of Haut-Banc du Nord.

Plate 25 represents the light-house of Haut-Banc du Nord (third order) in elevation and section, together with three sectional plans (Figures 3, 4 and 5) taken on the lines C D, E F and G H respectively.

In its general arrangements this structure conforms strictly to the type adopted for light-houses of the third order, isolated in the sea. The base consists of a solid mass of masonry, the rooms are located one above the other, and a series of small stairs gives communication between them and leads to the lantern. The diameter of the tower and thickness of the walls are not sufficiently great in light-houses of this kind to keep the rooms entirely shut off from each other, as is desirable and customary when circumstances allow.

The Haut-Banc du Nord is a limestone plateau, situated 3 000 meters off the northeastern extremity of the Isle of Ré. Almost horizontal, it has a length of about 450 meters, and a width of not more than 150 meters; it is cut up by numerous canals of various depths, and is only uncovered in very low spring tides, when the wind at the same time is off the shore. The rocky shoals which surround it only permit crafts of small tonnage to approach, and the winding courses of the channel render the approach difficult, even for the smallest boats at the time of low tide.

It was necessary to anchor the transports at some distance from the site of the light-house and transfer the material which they carried by means of barges. It is well known that great difficulties, and even dangers attend such operations when carried on, even while the sea is only slightly rough.

The foundation was established by means of a large iron grillage or bottomless caisson, of the form of a twelve-sided prism, about 14 meters diameter and 1.20 meters in height. It was formed by uprights distributed around its perimeter and in the interior at regular distances apart, and divided into three rows of horizontal iron framing. The pieces forming these horizontal frames or trellis-work were 0.07 of a meter wide by 0.01 of a meter thick, and united so as to form equilateral triangles, 2 meters to the side. The vertical posts were of round iron 0.02 of a meter in diameter. The total weight of the grillage was 11 440 pounds. Sustained by floats, this great apparatus was towed into place at high tide by a small steamboat, then grounded on the rock. After the tide had fallen sufficiently, and while it was not too rough, a movable flooring was placed upon the upper horizontal frame of the grillage, and there the workmen made the mortar and béton which were used for filling the caisson.

The lower part of the masonry was executed in béton, poured through copper tubes; these tubes were 0.30 of a meter diameter and 1.80 meters long, widened at the top, and had on their lower ends a projecting collar by means of which the béton was rammed in place. In order to prevent its being washed away, a temporary dam was made by means of plank panels supported against the grillage, which made still water in that part of the foundation where the work was being carried on. As soon as the water had fallen a sufficient distance to leave the surface of the béton uncovered, recourse was had to rubble masonry, as it could be laid with much greater rapidity, the workmen finding places to work, on the béton they had placed in position at high tide. The solid masonry thus executed was protected by a band of cut-stone, which was placed after the work of building the tower was completed.

The foundation was turned to good account before it was finished by fastening in it four spruce posts properly united together, which supported a crane used for distributing the materials of the solid part of the tower, which were landed by means of small shears placed at the foot of the structure. Held at first by guys, these posts were soon maintained in place by the masonry which enveloped them, and in it they were left. Above the first floor of the tower the central crane was raised as the work progressed, and two others were used for landing and handling material.

All the exterior facing of this tower was built of Kersanton granite, cut and dressed with great care.

The cost of the work was 330 985 francs It was commenced in 1849 and finished in 1853. The band of cut-stone protecting the base was not laid, however, until some years afterward. The structure was built by engineer M. Legros, under the successive direction of engineers-in-chief MM. Job de Soulangy and Leclerc.

Light-house of Triagoz.

The light-house of Triagoz (third order) is also established on an isolated rock in the sea, but its base was fixed above the level of the highest tide, and in consequence other arrangements than those of the light-house just referred to were made. It is represented on Plate 27. Figure 1 gives a front elevation; Figure 2, rear elevation; and Figure 3, a section through the front door and axis of the tower. Figure 4 is a sectional plan taken through the 10th tread of the stairway.

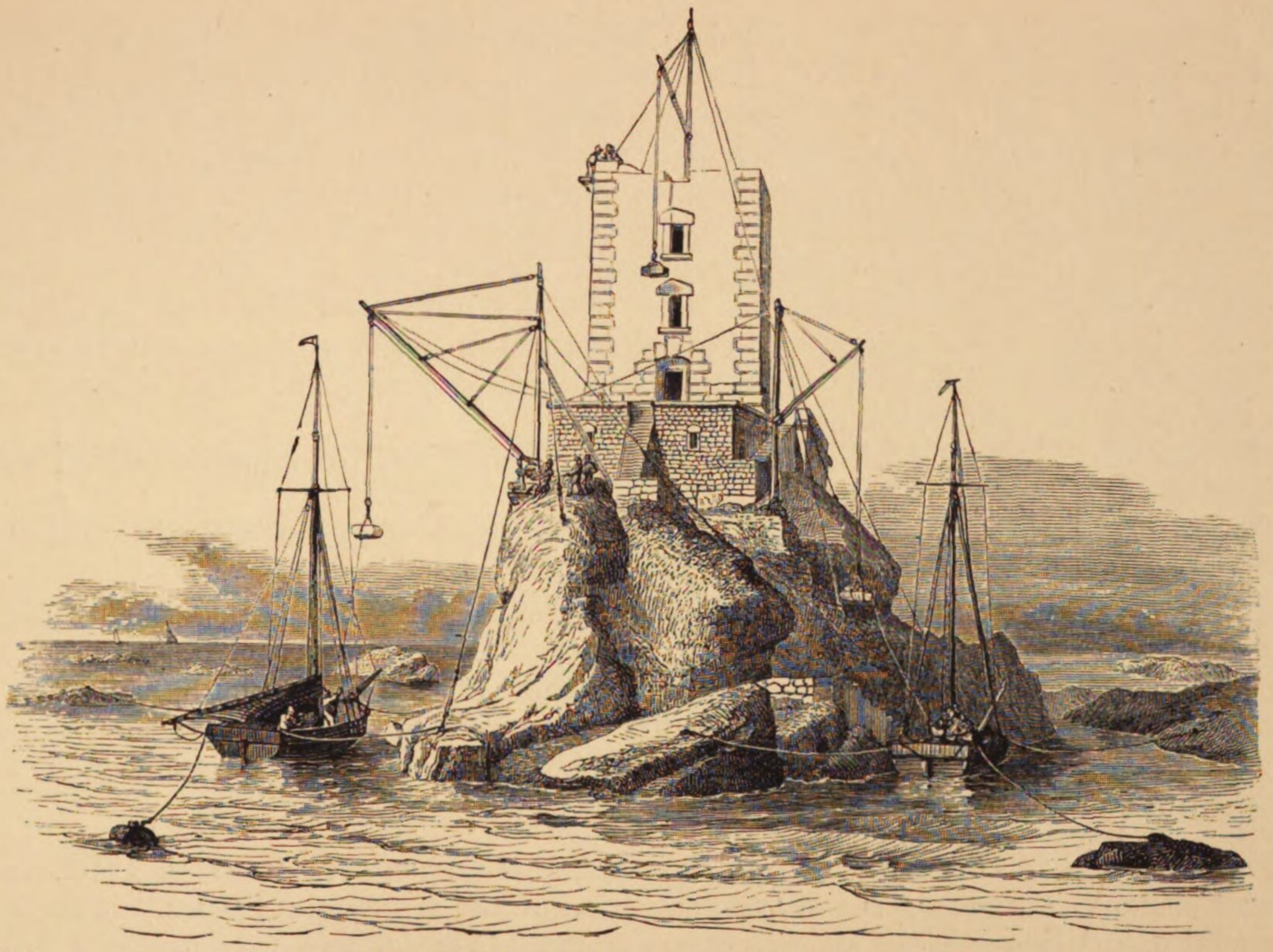
It will be seen that the edifice consists of a square tower, with a salient staircase inclosure on one of its faces. On the level of the first floor is a vestibule leading to the staircase, with a store-room on each side of it. There are three rooms above the ground-floor, one of which is reserved for the engineers. They are roofed over with cloistered arches and are provided with fireplaces. In the upper part of the tower is the watch-room, which serves at the same time as a store-room for implements that are to be kept free from moisture. The cast-iron stairway leading into the lantern starts from this room.

A platform conforming to the shape of the rock surrounds the edifice; it is reached by means of flights of stairs which are built in the side of the rock, starting from the point where the landing is least difficult. Under the front part, store-rooms are arranged for fuel and other materials, and a small building at one end adds a very useful appendage to the station.

The plateau of Triagoz is of considerable extent, being about four miles long from east to west by about one mile wide, but only isolated points of rock are exposed, even in the lowest tides. The rock selected as the site of this light-house is the most elevated point on the south side, and in consequence marks the northerly limit of the channel followed by coasting vessels. In front of the middle it has the appearance of an almost vertical wall, and on the opposite side it falls off with a depression in the surface, forming a small open creek. This is the most accessible place during three or four hours of low tide. The depth of water, which is 20 meters at the lowest tides at the foot of the rock on the south side, increases rapidly as you leave it; the bottom is rocky, and the tidal currents so strong that the plan originally intended, of keeping a vessel anchored here during the fine season to serve as quarters for the workmen, had to be abandoned.

It was therefore necessary to build a hut, after having leveled off the summit of the rock, on the part corresponding to the interior opening of the tower. It inclosed a vertical post set in the center of the structure, rigged with a boom for raising stones up to the work. The landing of materials was done by means of two derricks, one placed at the entrance of the little creek on the north, the other on the southeast end of the rock. They were worked with great rapidity whenever the sea was smooth enough for landings to be made. The design herewith (Figure 30) gives a view of the work at a period when the construction had been well advanced.

FIG. 30.



This work was executed in rubble masonry, with belting course, plinth, cornice, arrises, and openings of cut granite. The outside faces of these stones were dressed to give a fine appearance of rustic masonry.

The work was commenced in 1861 and finished in 1864, and was executed by engineer M. Poland, under the direction of engineer-in-chief, M. Dujardin.

The entire cost has not yet (1864) been completely determined, but it seems probable that it will not exceed 293 000 francs.

Light-house of Kermorvan.

The general arrangements of the light-house of Kermorvan are the same as those adopted for light-houses of the third order, (small model,) and smaller lights established on isolated rocks, not entirely submerged by the tides.

This edifice is represented on Plate 28, in which Figure 1 is an elevation of the front of the structure; Figure 2, a section on the line A B of the plan; Figure 3, a section on the line C D; and Figures 4, 5, 6, 7 and 8, sectional plans taken through the lines E F, G H, K L, M N and O P Q R. It will be seen that the tower is square in plan on the outside and circular inside, and that its two least exposed angles are occupied, one by the tower staircase and the other by a small closet. There is one room on each floor.

The rock upon which this light-house stands is separated from the mainland by a deep gorge, but communication is maintained by means of a stone bridge thrown across it.

The work is built for the most part of roughly-dressed quarry stone; the base, the cornice, and the balustrade being of a beautiful quality of cut granite.

The cost of the structure was 34 919 francs. It was executed by engineers MM. Plantier and Menu de Mesnil.

Light-house of Pontaillac.

The light-house of Pontaillac is used in connection with one at Terre-Nègre, forming a range to guide into the Gironde River. It is built of wood, in order that it may easily be moved in case changes in the channel should at some future time require a change in its location.

It is represented on Plate 29. Figure 1 represents half-plan of the lower part and half-plan of the watch-room; Figure 2 is a side elevation, upon which is shown the glazed opening through which the light from the apparatus passes; Figure 3 shows, on a large scale, the general arrangements of the framing, one-half in elevation, the other half in section; Figure 4 shows the manner in which the various parts of the frame-work are put together.

The structure consists essentially of four corner posts inclined toward each other, forming the outline of a truncated quadrangular pyramid, braced and tied together by means of horizontal ties, diagonal cross-braces, and three sets of longitudinal braces set on the faces of the frame. The staircase is comprised in a well, formed of four vertical posts in the center of the structure, which are braced by connections with the frame-work. The different pieces, where they cross each other, are held by iron bolts.

The base of the frame-work is established on a small wall of masonry, which raises it slightly above the level of the ground.

The service-room is located on the level of the upper platform, and the lantern-room immediately above it.

All the wood-work is made of Norway pine, except eight brackets that sustain the upper gallery, which are of oak.

A small house for the keeper is established a short distance from the light-house.

The total cost of the structure was 54 067 francs, of which amount, 34 910 francs were spent on the tower. The works were executed in 1856 and 1857, by engineer M. Botton, under the direction of M. Leclerc, engineer-in-chief.

Light-house of New Caledonia.

Plate 30 gives the design of an iron light-house, constructed at Paris in 1862, and sent to New Caledonia. Figure 1 is the front elevation of the structure; Figure 3 is the plan of the ground-floor; Figure 2 is a section through the tower on the broken line A B C D of Figure 3; Figures 4 and 5 are sectional plans taken through the lines G H and I J.

The larger number of iron light-houses executed up to the present time are formed of sheets of plate-iron of greater or less thickness, which are riveted together. This system

did not appear to be applicable at this place. In the first place, the durability of the edifice is made to depend on an envelope, which, exposed to rapid oxidation, cannot last very long, especially if the repairs are neglected; in the second place, the setting of the rivets and the manner of executing the work require special workmen, and the erection of stages of difficult construction, neither of which could well be done in a distant colony destitute of resources.

Certain conditions had to be fulfilled.

1st. To render the frame-work of the edifice independent of the exterior envelope, to protect it from the spray of the sea which is a cause of rapid oxidation, to so put it together as to render its inspection and repair easy, and to reduce as much as possible the extent of the surfaces that could retain moisture.

2d. To so arrange the different parts of the construction, that the tower could be put up without scaffolding carried up from the ground, and without the necessity of setting a single rivet.

It was also necessary that the different parts should be of such dimensions that no difficulties would be experienced in shipping, storing, unloading, or setting up at the site.

Sixteen uprights, each composed of fourteen panels, constitute the frame of the structure. Each panel is formed of simple T-irons assembled, braced and riveted, as shown in the section, in such a manner as to form a perfectly rigid system, and of such shape as would not be injured by any force that would be likely to be brought to bear on it. These panels are bolted together one over another; and connecting tie-beams on the inside and outside, also bolted to them, maintain the uprights firmly in position. Finally, upon these tie-beams or stays, and the exterior faces of the uprights, the sheets of iron-plating constituting the envelope are fastened, the joints of which are covered by fascia strips of iron fastened by bolts.

The greater number of bolts can ultimately be replaced by rivets if desirable, which would insure greater rigidity in the different parts of the structure.

Each upright carries at the top a cast-iron bracket, above which is established the projecting platform necessary to enable the keepers to reach the outside of the lantern, and rests at the base on a large cast-iron sill, to which it is solidly bolted; this sill is formed of five pieces bedded in a solid mass of béton.

In order to assure the necessary rigidity, the faces of the tower have a decided batter, and a large trumpet-shaped base. The object was attained; the oscillations of the tower under the action of the wind are less apparent than in many light-houses of the same height built of masonry.

Advantage is taken of the above arrangements to establish store-rooms and keepers' quarters in the lower part of the tower. The distribution is made as follows: (Figure 3;) *a* is the vestibule; *b b* are the keepers' apartments; *c c* are the store-rooms. In order that the panels, which run through the middle of each of these rooms, might not be an obstacle to free circulation through them, they were not braced by diagonal cross-pieces, as those that are shown on the section, but by trusses placed in the angles, as shown by dotted lines. The rooms are separated by brick partitions, and at a distance of 0.05 of a meter from the plate-iron covering of the tower, a brick lining is built, forming an air-space between the lining and the wall. An area of béton raises the floor 0 40 of a meter above the top of the cast-iron sills, and a masonry floor resting on small iron joists forms the ceiling above. A second tier of rooms can be established above the ground-floor at any future time if they may be needed.

A service-room is arranged near the summit of the tower; it communicates with the lantern-room by means of a cast-iron step-ladder, such as is generally used.

The stairway of the tower is of cast-iron with wrought-iron string pieces. The exterior stringer is bolted to the uprights that it crosses, and thus adds to the rigidity of the system. One-half revolution of the stairs corresponds exactly to the height of a panel, being 3.20 of a meter.

The entrance doorway and all the window-frames are made of iron.

The tower is painted with red lead; the base, the joint-covering strips, the cornice, and the balustrade being brought out in relief by a coloring of brown.

The work was set up by means of a derrick set on the tower, which was carried up as the work progressed, and a light flying scaffold suspended to the structure. It only took two months to complete the work.

The T-irons, the flanges of which are bent in so as to conform to the angles of the polygon, and which form the exterior edges or arrises of the light-house, are throughout their entire lengths 0.18 of a meter by 0.10 of a meter, and weigh 31 kilogrammes to the lineal meter. Those which make up the other three sides of the panels in the first three tiers are 0.20 of a meter by 0.10 of a meter, and weigh 35 kilogrammes to the meter; their section being reduced to 0.17 of a meter by 0.10 of a meter, and their weight per lineal meter to 31 kilogrammes in the next four tiers; and to 0.15 of a meter by 0.10 of a meter, and weight per lineal meter 23 kilogrammes from there to the level of the service-room. Through the service-room they are of the same dimensions as those in the lower panels. The cross-braces in the first three tiers are made of T-irons 0.15 of a meter by 0.08 of a meter, and weigh 22.50 kilogrammes to the lineal meter. The tie-beams uniting the uprights are formed of angle-irons with 0.08 of a meter flanges, and weigh 13 kilogrammes to the meter.

The thickness of the iron plating diminishes from the lower part of the tower, where it is 0.010 of a meter, to the top, where it is reduced to 0.007 of a meter.

The joint covers are of plate-iron 0.011 of a meter in thickness.

The cost of the work, including the setting up and taking down at Paris, was 228 706 francs, which is made up as follows:

| | Francs. |
|---|---|
| Castings for the sills of the foundation and base of the ground-floor, 82 093 kgs. @ 0.40 fr - - - - | 32 837.20 |
| Planed castings for doors, cornice, and stairs, 45 887.48 kgs. @ 0.55 fr. - - - - - - - - | 25 238.11 |
| Iron-plates, 193 466.89 kgs. @ 0.70 fr. - - - - | 135 426.82 |
| Wrought-iron fitted for stair-posts, stringers, railings, &c., 17 872.97 kgs. @ 1.40 fr. - - - - - | 25 022.16 |
| Painting with red lead, three coats, 5 059.23 meters @ 1 fr. | 5 059.23 |
| Brass-work, mahogany railing, glazing, models, &c. - - | 5 123.23 |
| Total - - - - - - - - - | 228 706.75 |

Light-house of Walde.

Plate 31 shows the designs of the light-house of Walde, which has already been referred to. The system upon which this light-house is constructed is especially adapted to those the foundations of which rest on sand that is covered by the tides. On account of the slight obstruction they make to the flow of the water, its piles do not produce the scouring action that it would be so necessary to prevent if the base were solid, and the screws with which they are provided enable us to force them in the ground to a great depth, while, at the same time, the large area of the flanges gives them great bearing surface, and consequently tends to prevent settlement.

The focus of the illuminating apparatus has an elevation of 10.85 meters above the level of the highest tides, and about 18 meters above the level of the fine-sand shoal upon which it is built.

The structure consists of six wrought-iron piles, placed at the angles of a regular hexagon, and one center pile, which together support a horizontal platform. On top of this platform the keeper's house, divided into several compartments, is established. A small circular cast-iron stairway leads from this room to the lantern above.

The piles are braced and tied together by means of struts and diagonal tension-rods, the latter being provided with turn-buckles. The overhanging gallery is supported by plate-iron brackets. The room is sheathed on the outside with plate-iron and on the inside with oak. The partitions are made of the same wood.

Figure 1 gives upon a small scale the plan of the base of the structure, and Figure 2 a plan of the keeper's room. On the right and left sides of a small vestibule are located a water-closet, and a store-room for oil, water, supplies, and fuel. Opposite the entrance is the sleeping-room, in which the location of the beds is indicated by dotted lines. The latter are habitually rolled up and packed in closets in the rear of each during the day. A kitchen-stove is close to the wall on the side of the room directly opposite the entrance-door. The stairway leading to the lantern starts from a point close to this door.

Figure 3 is an elevation of the light-house taken on the land side.

Figures 4, 5, and 6 give the plan, elevation, and section of the lower part of one of the piles. The piles are of wrought-iron, 0.152 of a meter in diameter; the screws are cast, the diameter of the flanges being 0.61 of a meter. They are attached to the piles by means of two key-bolts, one iron pin, and a wrought-iron collar.

Figures 7 and 8 represent one of the collars of the lower exterior piles to which the lateral and radial tension rods are attached.

Figures 9 and 10 show the manner of making the attachments of the twelve inclined tension-rods that come together at the central pile.

Finally, each pile is made in two sections, united together by means of a male and female screw, the lower section being more than 12 meters in length. Figures 11 and 12 give the details of the manner in which they are made fast to each other, and show how nine other pieces are united around the same point.

All the wood-work was executed in the best manner and with the best materials.

The planting of the piles was done by means of a set of shears composed of three legs, and a capstan worked by twelve men. The greatest precautions were necessary to insure accuracy in the inclination of the piles, to render an account of which would take more space than can be given to it.

The quantities of cast and wrought-iron which enter into the construction of this light-house are as follows:

| | Kilogrammes. |
|---|---|
| Iron forgings and plates | 39 628 |
| Cast-iron | 2 252 |

The cost of the work reached the sum of 107 665.73 francs, as follows:

| | Francs. |
|---|---|
| Construction of the work up to the gallery platform, according to contract with Messrs. Mitchell and Saunders | 82 500.00 |
| Custom-house duties | 8 365.73 |
| Room, upper platform, setting up, &c. | 16 800 00 |

This work was executed under the direction of Engineers MM. Legros and Leblanc.

Light-houses of the fourth order, with keepers' dwellings.

Figures 1, 2, 3 and 4 of Plate 32 represent the general arrangements frequently adopted for light-houses of the fourth order in connection with the keeper's dwelling. A small tower, square in plan outside and cylindrical inside, is inclosed in a house which contains on the ground-floor a room with a fireplace, an alcove for a bed, and three closets, one of which is used as a store room for implements, &c. A second room is arranged in the garret. The tower has a diameter of only 1.40 meters on the outside, and has a single full-neweled circular stairway extending from the base to the lantern The pedestal which supports the illuminating apparatus rests on the top of this newel, which, in order to furnish a seat of sufficient dimensions, has in the upper steps a diameter of 0.30 of a meter. In attending the apparatus the keeper stands on the top step of the stairway. This step should always be placed on the side of the unilluminated angle, if there be one, and it is generally made to include an angle of ninety degrees. In order to give head-room below it, three or four of the last steps are made with a rise of 0.25 of a meter. A small plate-iron table, called the service-table, rests upon the pedestal of the apparatus on one side and against the parapet

of the lantern-room on the other; a doorway is cut in the parapet on a level with the top step, which leads to the outside gallery.

When the illuminating apparatus is required to light only a small arc of the horizon the lantern and gallery are not required; it is only necessary to cut a large window in the tower in front of the illuminating apparatus.

The cost of a work of this kind depends, in a great measure, on local circumstances, and varies greatly between distant limits. It is estimated that the mean is about 12 000 francs.

Figures 8, 9 and 10 of the same plate give the designs of a small house arranged in a manner to receive a range-light apparatus, illuminating only a small angle. When the ground is sufficiently elevated above the level of the sea, the illuminating apparatus, which generally consists of a simple photophore, is placed on the first story, behind a window in the gable or an opening above the entrance doorway. When the elevation is not great enough, the apparatus is placed in a small lantern, which is hoisted between two guides resting on a frame bracket built against the gable of the building. The drawings show this last arrangement, which is only resorted to in case of necessity and for lights of minor importance, as they are not well arranged for regularity of service.

In some cases, where the height of the window suffices, and where it is necessary to light about one-half of the horizon, a small fixed lantern projects from the wall, the glass of which can be cleaned on the outside from lateral openings.

A construction of this kind costs from 6 000 to 10 000 francs, according to circumstances.

Figures 5, 6 and 7 of Plate 32 show an entirely new arrangement which has been adopted for light-houses to be erected on isolated rocks, requiring an elevation of more than 10 meters above the level of the highest tides, but so difficult of access that masonry structures would be very expensive and require too much time in their construction. It is somewhat similar, but on a small scale, to that of the light-house of New Caledonia, a description of which has just been given.

An interior frame of T-irons supports a plate-iron envelope. The joints of this envelope are covered by battens, riveted with it to the uprights and horizontal pieces. The T-irons and battens in the angles of the base of the structure are bent, so that the branches fall in the faces to which they belong. The uprights and horizontal pieces of the framing are united by furring pieces riveted to both, and are also held in place by diagonal ties.

The keeper's quarters are established at the foot of the tower, which contains a full-newel circular staircase; they are divided by heavy framing, which supports the ceiling and braces the uprights of the tower. An interior lining of brick, laid in Portland cement-mortar, protects the room from exterior moisture and changes in temperature.

The structure is held in place by three anchor-bolts to each vertical frame, and by four under the tower. The uprights of the vertical frames are formed of T-irons 0.18 of a meter by 0.10 of a meter, and weigh 31 kilogrammes per running meter. The T-irons of the tower are 0.20 of a meter by 0.10 of a meter, and weigh 35 kilogrammes per meter. The plate-iron of the base has a thickness of 0.008 of a meter, and that of the upper part of the tower is reduced to 0,005 of a meter The brackets of the cornice and plinth are of cast-iron.

Figure 5 represents an elevation of the edifice; Figure 6, a section taken on the line A B C D of the plan; and Figure 7, a plan of the ground-floor.

The cost of building a work of this kind, not including the cost of transportation and setting up, which depend entirely upon local circumstances, is estimated at 25 000 francs, as follows:

| | Francs. |
|---|---|
| Ordinary plate-iron, 25 500 kgs. @ 0.70 francs - - | 17 850.00 |
| Iron for hand-railing, window and door-frames, 1 440 kgs. @ 1.40 francs - - - - - - - - - | 2 016.00 |
| Castings, 7 000 kgs. @ 0.50 francs - - - - - | 3 500.00 |
| Contingencies - - - - - - - - - | 1 634 00 |
| Total - - - - - - - - - | 25 000.00 |

Figures 1, 2, 3 and 4 of Plate 33 give the designs of a small tower, built of cut-stone, of a style which has been frequently reproduced on our coast for the establishment of harbor lights. The interior diameter is fixed at 1.40 meters, and the stairway is arranged as in the cases of those with keepers' dwellings attached that have just been described. Figure 3 is a plan of the ground-floor, and Figure 4 is a sectional plan taken at the height of the lantern parapet

The cost of a work of this kind varies, according to local circumstances, from 6 000 to 10 000 francs.

Figures 5, 6, 7 and 8 represent a small tower of the same kind built entirely of iron. It is octagonal in plan, and the general method of construction is analogous to that described above. Iron battens to cover the joints of the angles of the tower are not always made use of, but sometimes, as in this case, the T-irons have the flanges bent inward at a proper angle and form joint-covers themselves. The plate-iron panels are riveted or bolted to them on the inside.

These small towers may be placed either on stone jetties or on cribs. They have the advantage of occupying less space than any of the structures before described, and are easy to move in case the extension of the jetties they mark renders it necessary.

The T-iron uprights are 0.18 of a meter by 0.10 of a meter, and weigh 30 kilogrammes per lineal meter. The sheets of plate-iron are 0 006 of a meter in thickness. The cost of a work of this kind is estimated at 10 000 francs, not including transportation and erection at the site.

Recourse is sometimes had to other arrangements for small lights, sometimes as a measure of economy, at other times in order that the structure may be more easily moved. The illuminating apparatus consists of a photophore. a sideral, or a small catadioptric apparatus, like those represented by Figures 5, 6, 11, 12, 13, 14 and 15 of Plate 12, and is inclosed in a portable lantern, which is hoisted between two guides resting on a frame made either of wood or iron. A small room is placed at the foot of the guide-frame, where there is room for this purpose, in order to allow the lamp to be lighted under cover. A part of the roof in this case can be removed in order to give passage-way to the lantern.

Figures 9, 10 and 11 of Plate 33 give the designs of a wooden structure of this kind. They show it supported on piles; sometimes it rests directly on the ground.

Figures 12 and 13 represent a section and lateral elevation of a guide-frame of this kind made of wrought-iron, with a room covered with plate-iron at the foot. This arrangement has the advantage of requiring less space than the other.

Finally, there is represented on Figures 14 and 15 a single cast-iron post with guide-rods. This system is not a very satisfactory arrangement, as the apparatus cannot be taken in under cover to light or to trim it; it is only employed on jetties of such limited width as to render its use absolutely necessary, and for lights of minor importance.

Light-ships.

The dimensions of light ships vary with the circumstances under which they are to be moored, and with the height to be given to the focus of the illuminating apparatus. Their strength should be regulated according to the depth of the water in which they are moored, the force and height of the waves in bad weather, and the height of the focus of the apparatus above the line of flotation. The tonnage of light-ships for our coast varies from 70 to 350 tons.

The vessels are narrow as compared with their length, so that they may offer as little resistance to the waves as possible; in the fore part of the vessel their lines, which below water-line are very sharp, spread out above in such a manner as to give them great buoyancy; the perpendicular section through the middle is almost rectangular; finally, bilge-keels placed on each side of the vessel run nearly through the entire length, and are designed to reduce the rolling motion as much as possible. The quarters and store-rooms are established between-decks; the anchoring cables are stored in the hold near midships.

A vessel may carry as many as three lights, but it is doubtful whether so many would ever be required. As these lights should be established at very unequal heights in order

to prevent blending, and as the maximum height at which it is possible to place them is limited, one of them must necessarily be placed so near the deck that it cannot be seen at a great distance; on the other hand, such an arrangement of three lights is not necessary, as it is always easy to prevent any danger of confusion with neighboring lights without using more than two.

The table herewith gives the principal dimensions and cost of establishing some of the floating lights on our coast:

| Name. | Position. | Depth of water at low tide. | Width of beam. | Length. | | Depth of hold. | Tonnage. | Number of lights. | Height of upper light above the sea. | Cost, not including the illuminating apparatus. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | On deck. | Of keel. | | | | | |
| | | *Meters.* | *Meters.* | *Meters.* | *Meters.* | *Meters.* | *Tons.* | | *Meters.* | *Francs.* |
| Mapon..... | In the Gironde..... | 6 | 5.66 | 18.33 | 15.75 | 2.66 | 70 | 1 | 10.00 | 30 400 |
| Talais ..... | Near the mouth of the Gironde. | 5 | 7.25 | 25.30 | 22.00 | 3.75 | 180 | 1 | 10.80 | 84 000 |
| Ruytingen .... | Off Gravelines..... | 8 | 6.50 | 25.00 | 21.00 | 3.80 | 150 | 1 | 10.50 | 110 000 |
| Minquiers..... | In the English Channel, at the southwest extremity of the plateau of Minquiers. | 38 | 7.15 | 28.00 | 25.00 | 3.50 | 185 | 2 | 12.00 | 155 000 |
| Rochebonne... | Off the entrance of the Gulf of Gascony, 33 miles from the Isle of Ré. | 50 | 8.00 | 35.60 | 33.00 | 4.35 | 350 | 2 | 14.00 | 265 000 |

Although the question so long discussed as to the relative advantage of iron and wood for hulls appears to have been decided in favor of the former, so far as the naval and commercial marine are concerned, it cannot be said to be yet settled in so far as it concerns vessels for floating lights. For such purposes, in fact, iron does not offer all the advantages which recommend it under ordinary circumstances, and some of its disadvantages become more serious.

One of the great advantages of the new system of construction is, that the hulls of vessels need not be so thick, and, in consequence, there is more free space below deck; of course this is without any real value in light-ships, where more space is already available than is absolutely required. The disadvantages of iron hulls appear to be as follows:

1st. Their bottoms become foul by the accumulation of barnacles and marine plants much sooner than those with wooden hulls covered with copper; the evil is not a great one when vessels are not kept continually at sea for a long time, and can be cleaned at sufficiently short intervals; but it becomes a matter of serious importance in cases of vessels that cannot often be removed from their stations, and it should be remarked that whatever injures the sailing qualities of a vessel also tends to make her ride less easy at anchor.

2d. While the union of the parts is more complete in the iron than in the wooden vessel, it is to be feared that the rivets, which are subjected to the most violent shocks when the vessel is anchored where the sea is rough, may be sheared off, or they may tear the iron plating and thus occasion leaks which it would be difficult to stop; this danger might be avoided undoubtedly by providing some special devices, but it could be done only at a considerable increase in the cost of the vessel.

3d. In case the vessel should part her moorings and be cast on a neighboring rock, the iron hull would doubtless receive much greater damage than the wooden one.

There still remains for iron the advantage of greater durability; but this is, in a measure, balanced by the increased first cost, which is much greater for iron than for wooden vessels.

In fact the majority of English light-ships are built of wood, and among them that of the Seven-Stones, near the Scilly Islands, the most exposed on their coast. Those on the coast

of Ireland and some of those at the mouth of the Mersey are built of iron, but they are not moored in places where the sea becomes very heavy. All the light-ships on our (French) coast have wooden hulls.*

It is, however, to be noticed that the disadvantages attending the use of iron in a great measure lose their weight, if they do not entirely disappear, when it is a question of relief vessels, which can come into port at regular intervals to be put in order; these vessels are kept at their anchorages only during the good season, and but for a short time, so that we need fear neither the fouling of the bottom nor long-repeated violent shocks. These considerations appear of a nature to incline the balance to the side of iron, for vessels of this kind. Whatever may be the material used in their construction, vessels for floating lights should have much more strength than is generally given to those of the same tonnage used in the merchant service.

Mode of anchoring.

Two principal systems are in use to maintain floating lights in position: one with a single anchor, the other with two anchors and a bridle. The latter arrangement is more costly than the former; but it has the advantage, in places where good anchorage is difficult to obtain, of offering greater security, and, in case the light is a leading one, it holds the vessel nearer to her true position. It is necessary in bad weather that a vessel should have plenty of chain out, but as the bridle adds to the length of the mooring, it is not necessary to run out so much from the vessel as when a single anchor is used; the curve in which the vessel is free to move in this case has its center at a point midway between the two anchors, instead of at a single anchor.

It is readily understood that there is no precise rule for fixing the weight of anchors to be used, the strength or the length of the chains. Neither the force that will be exerted by the sea nor the proper resistance to meet it admits of any very accurate valuation; experience acquired under circumstances somewhat analogous to that of the case to be decided, is the only guide, and in default of theory we are limited in such matters to reporting facts. The following have reference to light-ships in the French service:

The Talais light-ship, moored at the mouth of the Gironde, upon a sand-bar, having a depth of water at low tide of 5 meters, is held by two single-fluke anchors, placed in the direction of the current, each weighing about 700 kilogrammes, and united by a bridle-chain 170 meters long and 0.035 of a meter in thickness; a mooring-chain of the same strength and 100 meters long, of which only 25 meters are habitually out, is attached to this bridle; each anchor is backed by a buoy anchor weighing 400 kilogrammes, held by a 0 020 of a meter chain 25 meters long; buoys with 0.018 of a meter mooring-chains 22 meters long.

The Ruytingen light-ship, in the North Sea, at about 3 miles in a direction north, sixteen degrees east, from the light-house at Gravelines, is moored on a sandy bottom, in 8 meters water at low tide. It has two single-fluke anchors, placed in the direction of the strongest tidal currents, of 1 200 kilogrammes weight, united by a 0.038 of a meter bridle 200 meters in length, to which a mooring-chain of the same strength and 100 meters long is attached; each anchor is backed by a buoy-anchor at 80 meters distant, in line with the bridle, with a chain 0.025 of a meter diameter, to which is attached a watch-buoy, the mooring of which is a 0.030 of a meter chain 30 meters long.

The Rochebonne light-ship, in the ocean, at the entrance of the Gulf of Gascony, 33 miles west, five degrees south, from the light-house of Baleines, upon a station where the sea attains great violence, is anchored upon a sand and gravel bottom, in 50 meters water at low tide. The mode of anchoring at first adopted was as follows: two single-fluke bridle-anchors, each of 2 000 kilogrammes in weight, each backed with an anchor of 1 000 kilogrammes; a buoy-anchor attached to one of the backing anchors by a chain 300 meters long and 0 020 of a meter in diameter; buoy mooring 0.030 of a meter diameter, 150 meters long; length of the bridle-chain connecting the main anchors 400 meters; the backing chains 75 meters. The mooring-chain of the vessel 500 meters long; diameter of these chains 0 046 of a meter.

*All the light-ships on the coasts of the United States have wooden hulls.—P. C. H.

The vessel having parted her moorings, was held, until she could recover her old anchorage, with a single-fluke anchor of 4 000 kilogrammes, backed by another of 2 000 kilogrammes. A buoy whose moorings are attached to the mooring-chain of the vessel will allow this chain to be recovered, in case of another accident, without the necessity of taking up the anchors.

The Minquiers light-ship, in the English Channel, at the southwest extremity of the plateau of Minquiers, anchored on a sand and gravel bottom in 38 meters water at low tide, (now building,) is to be held by a mushroom anchor of 3 000 kilogrammes, with a mooring-chain 360 meters in length and 0.038 of a meter in diameter.

Personnel of light-ships.

The personnel of a light-ship varies according to its size and the exposure of the station. It is generally so organized that the officers can have a month's leave of absence, and the sailors a fortnight every other month, except in extraordinary cases.

Each light-ship in the Gironde has a captain, a mate, four sailors, and a cabin boy; there are never less than one officer and three sailors on board at one time.

The Dunkerque light-ship has the same number of officers and nine sailors; at least one officer and six sailors always on board. This number, however, does not appear sufficient for the service of a ship which has a flashing light, and it is probable that two more men should be added in such a case.

The Minquiers light-ship is also to have two officers and nine sailors.

Finally, the Rochebonne light-ship has a captain, a first and second mate, sixteen sailors, (two of whom are carpenters and two bakers,) and two cabin boys. There are always at least fourteen men on board.

The lights on this ship have not yet been exhibited, (1864.) Some persons competent to judge, having expressed doubts as to the possibility of maintaining a vessel at anchor at that place, it has been deemed only prudent to make a trial before establishing lights on her.

Arrangements below deck.

A light-ship is so arranged below deck as to give convenient sleeping apartments to the crew, and such room as may be necessary for storage of material for the service of the light as well as the vessel. The cabin is in the after part and has attached to it four state-rooms—one for the captain, another for the mate, and two for the engineers and assistant engineers, who may on occasions be obliged to remain and sleep on board. The forecastle is in the bow, and opens into the sailors' ward-room. In the center of the vessel the various store-rooms are distributed. On deck, at the foot of the mast which carries the lantern, is a small house, in which the lantern is kept during the day, and which allows the cleaning of the apparatus to be done under cover.

Plates 34 and 35 give the drawings of the Ruytingen light-ship, as follows:

The Ruytingen light-ship.

PLATE 34.—Figure 1. The lower part of this figure represents the half plan, showing the ship's lines, and the upper part the starboard half of the deck; *a*, the apparatus room; *b*, the companion-way; *c c*, sky-lights; *d*, the windlass for hoisting the illuminating apparatus; *e*, the winch; *f*, the hawse-pipe; *g*, the water-closet; *h*, the pantry; *i*, the pump; *k*, the chain-pit.

Figure 2 is a plan of the rib-timbers.

Figure 3, end elevations, one half bow, the other stern.

Figure 4, side elevation, the line of flotation being taken parallel to the keel; the bow is elevated in reality, and the difference in the draft of water at the bow and stern is about 0.40 of a meter. Only the starboard landing boat has been indicated on this design. The lantern is down, and the position it occupies at night is indicated in dotted lines.

PLATE 35.—Figure 1 is a plan of the lower deck; *a*, is the saloon; *b b*, state rooms of the captain and mate; *c c*, spare state-rooms; *d*, pantry; *e*, office; *f*, the store-room for materials relating to the illuminating apparatus; *g*, the kitchen; *h*, store-room for rigging; *i*, ward-room; *j j*, sailors' state-rooms; *k*, the store-room for ship chandlery; *l*, carpenter's shop; *m m*, store-rooms; *n*, machine for revolving light apparatus; *o*, companion-way.

Figure 2 is a longitudinal section.

Figure 3 is a midship cross-section. The mast and day-mark on it are represented in elevation on this figure, and the dotted lines show the position of the lantern during the night.

# CHAPTER IV.

## LIST OF LIGHTS ON THE COASTS OF FRANCE JANUARY 1, 1864.

* * * * * * * * * * *

### SUMMARY.

On January 1, 1864, the number of lights on the coasts of France was 275, as follows:

| | |
|---|---|
| Lights of the first order | 43 |
| Lights of the second order | 6 |
| Lights of the third order | 35 |
| Lights of the fourth order, or small lights | 186 |
| Floating lights | 5 |

The expenses incurred since 1820 for the construction of the edifices which support these lights was 12 146 122.57 francs, (about $2 429 824.51.) The cost of establishing the illuminating apparatus now in place is estimated at 3 798 410.20 francs, (about $759 682.04.)

# PART II.—BEACONAGE.

## CHAPTER I.

### I. DAY-MARKS.

Every object in nature that gives a distinguishing characteristic appearance to a part of the seacoast may be considered a landmark; it being only necessary that it should be seen at a great distance, and not be liable to be mistaken for another. Light-houses, steeples, wind-mills, houses, peculiarly-shaped rocks, clumps of trees, forest glades, or long open passages between fixed sand-hills, sometimes even the sandy beach, when its limits are plainly marked, may furnish the mariner the means of determining his position with accuracy, or indicate to him the course he is to follow to avoid rocks and shoals.

Day-marks are necessary in order to enable the mariner to determine at once whether a buoy or light-ship has drifted from its proper position. Two ranges, and consequently four day-marks, are necessary to determine with accuracy a turning point in the channel, or indicate the position of a danger.

In constructions which are designed to be exclusively used as day-marks, three principal things are to be considered—the dimensions, the form, and the color.

Dimensions.

The dimensions evidently depend, all other things being equal, upon the distance at which it is desirable that the object should be seen. But the distance at which a body is visible, varies between very distant limits, according to the degree of transparency of the atmosphere, as well as the manner in which the light falls on the body itself, and also as it contrasts with the color of the background. Now these conditions cannot be accurately defined, and they vary greatly in themselves; it would be a great mistake to expect to determine, from a few experiments made at short distances, the dimensions that ought to be given to a day-mark to render it visible a great distance. It is better in such cases to be governed by the opinions of mariners. They agree very generally that a wind-mill of the ordinary dimensions—that is to say, having a diameter of about 7 meters and an elevation above the ground of from 10 to 11 meters—can be used as a day-mark at 7 miles distance when it is projected against the sky, or when painted white it is projected on a background of foliage. From this fact, the dimensions such a structure should have in order to be visible at a less distance may be deduced, admitting as sufficient, a width that would subtend at the observer's eye an angle of 1′ 51″. But this angle will not be large enough if the distance at which the object is to be seen is materially increased; it will be necessary to increase it somewhat, in order to compensate for the loss of distinctness of colors, and correct the effects of irradiation when it has the appearance of a dark object on the background.

Thus, upon the heights of Plouha (northern coast) a day-mark built of masonry, which is intended to mark the channel of Bréhat, the entrance of which is about eleven (11) miles distant, is projected as a dark object on the sky. It consists of a vertical wall 12 meters wide and 17 meters high, set so that the direction of the axis of the channel is normal to its face. The visual angle subtended by it at the limit of the range is found to be 2′ 1″—that is, a little greater than that of the wind-mills, of which we have just spoken, seen at a distance of seven miles, and yet mariners find that even this is not plainly visible.

To determine the law for properly increasing the visual angle to correspond to the increase of distance at which it is to be seen, would be a difficult undertaking and of doubtful utility. We start with the assumption that there is nothing definite in regard to it. It is only necessary to keep within a certain inferior limit, and not to forget that it is in the interest of navigation to have day-marks as plainly visible as possible. The more important the day-mark the greater is the necessity of giving it large dimensions.

It may be added, that up to a certain point, that which is wanting in width may be compensated by an increase in height. The day-mark of Plouha would probably be visible a sufficient distance if its height were increased one half.

Forms.

For day-marks built of masonry the rectangular form is most generally adopted. Shafts, however, have the disadvantage that their tops soon become indistinct, and are not projected so sharply on the sky as a horizontal line.

When the structure is only to be seen within a small angular space, as generally happens, it consists of a small wall supported by counterforts, its front being on a line at right angles to the bisecting line of the angle. These counterforts should be placed against the back of the wall, where the day-mark is projected as a white object on the background, because their shadows render it less distinct if located on the front. It is necessary to adopt the prismatic form with a square base in cases where the structure is to be seen from points of the horizon that are far apart. The cylindrical form does not answer the purpose nearly so well, as the solar rays give it two different aspects, one in the light, the other in the shade, and it then becomes less plainly visible, no matter what may be its color. The same effect is undoubtedly produced upon a prism when viewed at an angle with the direction of the rays of light; but what is lost in this case is made up by the increase of apparent width.

The forms of day-marks built of wood are much more varied, because this system of construction allows more latitude in this respect. These generally consist of a platform which supports a plank frame with close or open joints, forming variously-shaped structures. A signal being more or less plainly visible as the elevation is greater or less above the surface of the ground, the pieces which are intended to give the day-mark its characteristic form are placed on the upper part. The open-joint work has a double advantage over the other, it is less expensive and offers less resistance to the wind; but it has the disadvantage of being less plainly visible, because it is not so clearly defined on the background. The defect is less apparent, however, when the system in question is applied to spherical or cylindrical surfaces, and when the object projected is dark; because, in this case, the strips on the face opposite to the spectator help to fill up the voids on that of the front, and are at the same time in the shade. It is readily understood that the effect would be totally different if the day-mark were white.

Plate 36 gives the designs of several day-marks built of wood on the coast of Landes, where, to prevent too much uniformity in appearance, various characteristic shapes are given them.

Figures 1, 2 and 3 represent the plan and elevation of the structure that marks the sand-hills of Biscarosse, situated half way between the light-houses of Arcachon and Contis. This structure is built entirely of pine wood. Its signal or distinguishing mark is circular, with an interior opening of the same shape in the middle.

Figure 4 is the elevation of a large day-mark at Cape Bréton, the general arrangements of which are the same as those of the preceding one.

Figure 5 represents another form of distinguishing mark sometimes used.

Figures 6 and 7 give the front elevations and side view of a day-mark of less dimensions, of which there are numerous examples on our coast.

Some day-marks built of wood, that are to be seen from many different directions, have been built of the form of rectangular towers, surmounted by cages or other distinguishing marks of greater or less dimensions, depending on circumstances.

No day-marks have yet been built of iron, because it is not believed that its use would be as economical as wood or stone.

As to the proper colors to be given day-marks, it is well known that an object is more or less plainly visible, in proportion as it is more or less light and the background upon which it is projected is more or less dark. When the background is of a light color the object ought to be dark; but in this case the well-known phenomena of irradiation are produced, and this reduces the apparent width and consequently the distance at which it is visible. In order to be properly understood, the following experiment will be cited: Color.

A white card was divided into two equal parts by a vertical band of very deep black; a black card was divided in the same manner with a white band; four other cards, two of a light gray and two of a dark gray color, were divided in a similar manner, with white and black bands. Each card was 0.30 of a meter square, and each band was exactly 0.005 of a meter in width.

These cards were made fast at the same height to a wall of a gray tint; the weather was clear and the sky just sufficiently clouded to mask the sun. The observers, five in number, stationed themselves at such a distance from the wall that they could not see the bands, then they approached, and the distances at which the bands became distinct were noted for each of them.

The following table shows these distances, as well as the corresponding visual angle subtended by the bands. The observers designated by numbers 2 and 3 were always in accord; the differences between numbers 4 and 5 were so slight that they were not deemed worthy of notice, and are reported as alike:

| No. of the observer. | White, upon black. | | White, upon dark gray. | | White, upon light gray. | | Black, upon white. | | Black, upon light gray. | | Black, upon dark gray. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Distance. | Angle. | Distance. | Angle. | Distance. | Angle. | Distance. | Angle. | Distance. | Angle. | Distance. | Angle. |
| | *Meters.* | *Secs.* | *Meters.* | *Secs.* | *Meters.* | *Secs.* | *Meters.* | *Secs.* | *Meters.* | *Secs.* | *Meters.* | *Secs.* |
| 1 | 270.82 | 2.0 | 154.00 | 3.4 | 52.05 | 9.9 | 137.00 | 3.8 | 137.00 | 3.8 | 126.40 | 4.1 |
| 2 and 3 | 270.82 | 2.0 | 138.07 | 3.8 | 55.23 | 9.3 | 134.88 | 3.9 | 135.95 | 5.8 | 126.40 | 4.1 |
| 4 and 5 | 157.80 | 3.3 | 92.00 | 5.6 | 28.68 | 18.0 | 88.16 | 5.9 | 101.96 | 5.1 | 63.73 | 8.0 |

Several observations of interest may be drawn from this table. It will only be remarked that, for persons with ordinary sight, the black is brought out better when projected on a light gray than on a white background. This is an effect of irradiation.

The visual angles subtended by the bands are very much less than those which, it has just been stated, were generally used for day-marks that are to be plainly visible at a distance of several miles; but the distances at which the experiments were made, were so short that the effects due to the opacity of the atmosphere could scarcely exercise a marked influence on the results, and in practice, this is a most important consideration. The distinctive color is lost in the distance, and objects are not so sharply defined on the background, whatever may be their relative colors.

It would be necessary to accurately define the gray tints, if it were desired to give to the figures in this experiment any scientific value; they are only produced, however, to give an approximate idea of the importance of colors in the phenomena in question. They fully justify the rule adopted in the Light-house Service—that those objects which, to the eye of the mariner, are projected on the sky (which corresponds to a white or light-gray background) ought to be painted black, or at least some dark color, and those which are projected on land (black or dark gray) should be painted white. This rule is occasionally applied with extreme rigor; and there are to be seen on our coast towers painted black above and white below, without any regard whatever to their architectural divisions.

## II. BEACONS.

Beacons are structures designed to mark submarine dangers. They are established in various ways.

Wooden beacons.

Some consist of long pieces of timber from 0.25 to 0.40 of a meter diameter The arrangements adopted to secure them in place depend on the nature of the bottom. If it be sand or mud, they may be secured at their lower ends to a grillage or shoe, which is covered with an enrockment of stone, or they may be made fast to piles. If the bottom be not uncovered at low tide, recourse is sometimes had to a grillage resting on piles, which are cut off below the level of low tide. Sometimes in place of the grillage an old boat may be substituted, or a flat-bottom caisson; the beacon is then fixed at the lower end in the same manner as a mast in a vessel; the time of grounding the boat or caisson is arranged so that as the tide falls there will be time to lay a certain quantity of masonry to hold it in place, and then fill in with dry stones or béton. If it be a question of establishing one on the head of a rock which is uncovered at low tide, a hole is drilled of a diameter somewhat greater than that of the beacon, and of a depth which varies with the nature of the rock, but which is rarely less than one meter. This hole is larger at the base than at the top, and the beacon is well keyed, so that it cannot be raised. The keys, the tops of which come a little above the surface of the rock, are fastened to the beacon-post by means of iron bolts. The spaces between them are then filled in with mortar or bituminous mastic.

When the rock is always covered with water, a mass of masonry is built on top of it in a way that will soon be described; and there is bedded in it a cast-iron socket into which the beacon-post fits and is firmly keyed. Recourse is had to this system only in rare cases. It is better to establish a small tower at once, as it is necessary to build the foundation of masonry, or else use an iron beacon if the surface be not of sufficient area to place on it a masonry structure.

Wooden beacons are generally surmounted with balls, cylinders, or signals of some other form, designed to give them characteristic marks to distinguish them from others in the vicinity, and to render them more plainly visible. They have the advantage of being cheap, but are frequently carried away by the sea or by something fouling with them, and cannot be seen at a great distance. They are only suitable for interior waters where it is not necessary to see them at a great distance. There were formerly a great number of them on some parts of our coasts, but they have been in a great measure replaced by more durable and substantial structures.

The name floating-beacon is given to a stick of pine wood, one end of which is made fast to an anchor by means of a short chain, the other end being allowed to stand up at a certain height above the level of the water. This kind of beacon is less desirable than the other, and is only employed in interior shifting channels; small buoys are preferable to them in every respect.

Iron beacons.

Iron beacons, consisting of a single shaft, whether held or not by braces, have the same disadvantages as wooden ones, only in a less degree. They are always preferable, however, on account of their greater durability. It is sometimes necessary to use them, as when the surface of the rock is not of sufficient extent to receive a beacon built on several legs nor a structure built of masonry.

Beacons resting on several legs are composed of 3, 4, or 5 wrought-iron shafts, fastened in the rock in the same manner as the single-shaft beacon. The system is rendered rigid by horizontal ties and diagonal cross-braces. They are also generally united in the upper part by means of planks or strips of plate-iron placed horizontally at regular intervals, and surmounted by a signal or cage, which gives it a distinguishing appearance. They are more solid and much more plainly visible than the others.

Figures 8 and 9 of Plate 36 represent the plan and elevation of a beacon of this kind which was established on the rock of Antioche, to the north of the Isle of Oléron.

The summit of this rock is 2.77 meters above the level of low tide and 3.43 meters below that of high tide. The place is difficult to reach, and there was no port in the vicinity, at the time the question of establishing the beacon was under consideration. A project for a masonry tower 14 meters high was estimated to cost 70 000 francs, and it is probable that this estimate might have been considerably overrun. The engineers also gave it as their opinion that it would take several years to execute the work. For these reasons it was decided to build the beacon of iron.

It consists of four wrought-iron piles, 0.14 of a meter diameter, inclining inward, and corresponding to the edges of a truncated quadrangular pyramid, solidly united together and to a central pile, and spaced so that they were 4 86 meters apart from center to center at the bottom and 2.50 meters apart at the top. They were surmounted by a structure of the same kind, of the form of a rectangular prism, terminating in a pyramid, which is crowned by a sphere 1.30 meters diameter.

Each pile is keyed in a cast-iron socket, which is bedded in the rock with masonry laid in cement, as shown on Figure 10. The rock is of rather soft limestone, and the dimensions of the holes made for bedding the feet of the piles were made large on that account.

The top of the beacon is 13.80 meters above the level of the rock and 10.47 meters above the level of the highest tides.

The central pile has a ladder, which is carried up to the base of the pyramid, on top of which there is an iron platform, which serves as a refuge for people who may be wrecked on this shoal.

Planks, placed at regular distances apart, cover the faces of the pyramid and the square portion below it for a distance of 1.6 meters. The whole structure is painted red.

It only took one month to completely set the beacon up on the rock. The work commenced on the 28th of August, 1858, and was finished before the end of September following. The beacon has stood since that time. The iron beacons, consisting of a single shaft, which were formerly used to mark this danger, were frequently carried away.

The cost of the work was 20 947.90 francs, made up as follows:

| | Francs. |
|---|---|
| 14 434 kilogrammes of iron forgings at 0.95 franc, including setting up at the foundry, painting, taking down, and transportation to the Isle of Oléron - - - - | 12 762.30 |
| 1 976 kilogrammes of castings at 0.60 franc - - - | 1 185.60 |
| Setting up at the site and contingencies - - - - | 7 000.00 |
| Total - - - - - - - - - | 20 947.90 |

The price of iron is considerably lower now (1864) than it was then.

A few cast-iron beacons have been built on our coast, but this system of construction has been almost entirely abandoned. The piles were cast solid, and the beacons built in the same manner as when wrought-iron piles are used. Cast-iron is objectionable, however, on account of its brittleness; it necessitates the use of piles of larger cross-sections, and was more difficult, therefore, to erect at the site. If we have recourse to hollow castings, the diameter of which is necessarily limited, the beacon is less plainly visible than a wrought-iron one with several legs, and is more in danger of being destroyed by accident.

Masonry beacons.

Beacons built of masonry are far preferable to those built of any other material, both on account of their superior durability and the greater distance at which they are visible. A large number of them have been built in the last few years on our coast.

These masonry structures were formerly very expensive. It was thought necessary to use cut-stone, at least for the exterior faces, and the stones had to be united by means of hooks or cramps. Now, by the use of quick-setting cements, and especially Portland cement, there is no necessity of using cut-stone at all. All our beacon-towers are now built of rubble

masonry entirely, using stones of small dimensions, the exterior ones being roughly picked on the outside, and filled in behind with common rubble or béton. The economy resulting from this system of construction is not alone in the cutting of the stone; the transportation of material is more easy and rapid; it is no longer necessary to employ exclusively skilled masons as common laborers soon learn to lay ordinary rubble; the work, after it has once been commenced need not be stopped by the loss of a single stone, as is the case sometimes when dressed ashlar is used; finally, a small tower, such as formerly took several seasons to build under the old system, can now be built in a few months. Formerly the profile of the lower part of our beacon-towers was generally made concave; such is no longer the case: all our masonry beacons are now built of the form of a frustum of a right cone.

Our beacon-towers on the shores of the English Channel and the Atlantic Ocean are constructed upon rocks the tops of which are bare at low tide. They are sunk into them to a depth which varies with the nature of the rock, and is never less than 0.20 of a meter; this manner of sinking the base of the structure into the rock is only applied, however, to the face-wall; it is sufficient for the remainder to pick the surface of the rock, so as to remove all traces of marine vegetation, in order to secure a good connection between the rock and the beacon. The adhesion of the masonry to the rock being inferior to the cohesion of its parts, as experience has proved, strong iron bolts buried partly in the rock and partly in the masonry of the tower, are sometimes made use of to render it immovable. When the rock is only slightly elevated above the level of the lowest tides, the lower courses of masonry are laid in quick-setting cement-mortar, or they may be laid in pure cement Starting from the level of neap tides, or a little above, according to the exposure of the site and the liability of the sea to wash over it, this system is applied only to the face-wall to a depth of 0.60 of a meter, and Portland cement-mortar is used for the interior; finally, above high tide, Portland cement-mortar is used exclusively for both inside and outside it being sufficient to point the joints with pure cement before the return of the tide covers the work. Some towers built of rubble masonry of poor quality have been covered with a coating of cement or stucco

The cement generally employed is either Parker or Portland cement, imported from England or procured at Boulogne It is known that these mortars have not been decomposed by sea-water up to the present time, but it is doubtful whether we can count on this never taking place; however, in case decomposition takes place at any future period, it will first manifest itself on the outside, and it will be easy to remedy it.

The summits of beacon-towers ought to have an elevation of at least 3 meters above the level of the highest tides. Those which should be seen at a considerable distance should be higher, or be surmounted by a mast or frame which is crowned with a signal or cage. Recourse is sometimes had to this arrangement in order to distinguish towers where there is danger of one being mistaken for another.

The majority of beacon towers are provided with galvanized iron handles and a safety ladder. They are surmounted on the upper part by a balustrade of the same material. Some have on their summits a small room arched over with masonry.

The diameter of the base of these towers is generally fixed at one-half the height, but it is never less than 3 meters, and has a batter of $\frac{1}{10}$. This proportion is justified by experience, but it is easily understood that there is no absolute rule in the matter, and that if the diameter and height are increased at the same time they need not be in the same proportion The heights of these towers do not vary greatly, and no precise rule in regard to the relation between height and diameter at the base is necessary.

The cost of building these towers depends upon local circumstances, the difficulties of landing, and especially the condition of the sea during the time the work is being carried on. They vary, consequently, between very wide limits. There are towers which have not cost more than thirty francs per cubic meter; for others the cost has been as high as two hundred francs per cubic meter.

Figure 11 of Plate 36 represents a beacon-tower seven meters diameter at the base, the top of which, not including the cage, stands four meters above the level of the highest tides.

On the Mediterranean the difficulties of construction are generally much greater than upon the Atlantic coast, because most of the rocks to be marked are never uncovered. The foundations are generally executed in concrete or béton, made with a quick-setting cement, which is poured into a bottomless caisson grounded on the shoal, or in a coffer-dam sustained by iron uprights imbedded and fastened to the rock. The mass of concrete is carried up to a certain height above the level of the sea, (from one-half to two meters,) and the tower is built up with an offset on this as a foundation.

There may be cited, as examples of this mode of construction, the tower of Aloze, at the entrance to the harbor of Brescon, of Cassidaigne, upon the coast of Province, between the ports of Cassis and Ciotat; and of Cride, in the bay of Saint-Nazaire. The Aloze is a very uneven rock, upon which a heavy sea breaks most of the time, and the depth of water on it varies from 1.65 meters to 0.70 of a meter at the site chosen for the construction. The top of it was cut down and cleared of all marine plants by a diver, and the union of the masonry with the rock was rendered more certain by eight strong iron bolts. A bottomless caisson, octagonal in plan, of 4 5 meters diameter, the top of which was 0.08 of a meter above the level of the water, was floated out and grounded on the rock; the caisson was then filled with concrete, which was placed in such a manner as to prevent its being washed away. The lower layers of concrete were made with Portland cement, to which was added some Valentine cement, which sets very rapidly. The tower proper was built of rubble masonry, commenced on top of this mass of concrete, which was leveled off even with the top of the caisson, and the two parts of the work were united by means of long stones which were bedded to the depth of 0.35 of a meter in each. The outside was then covered with a coating of cement.

This tower has a diameter of 3.5 meters at the base, 2 58 meters at the top, and is 5 20 meters high.

The total cost of the work was 9 225 francs, of which 6 377 was for the foundation and 2 847 for the upper part, which makes the cost of the rubble masonry, including the coating of cement, 73.37 francs per cubic meter.

The small dimensions of the structure enabled the caisson to be filled with concrete in thirty-six hours, and as the work could only be done while the sea was calm the utmost celerity was necessary in its execution. The work would probably have been carried away if a heavy sea had arisen before the foundation was completed.

The tower of Cassidaigne is considerably larger, and is much farther from the mainland. Other arrangements were necessary in order to secure a foundation for this structure.

The rock is situated nearly four kilometers from land, in a place where the sea sometimes attains great violence. The structure consists of a cylindrical tower, widened at the base, resting on a large mass of concrete, and crowned by a small arched room, which is surrounded by a platform with a balustrade. A ladder fastened in the masonry of the structure leads to this platform.

The surface of the rock below the level of the sea varies from 1.75 meters to 5.80 meters throughout the whole extent of the base. The platform of the tower has a height of 17 20 meters above the same level. The mass of the foundation was 12 meters in diameter, and was carried up two meters above the level of the sea. The diameter of the tower, which is 6.1 meters at the base, is reduced to 3 50 meters just below the cornice

In order to build the mass of the foundation and support the movable platform upon which the workmen stood and prepared the béton, recourse was had to iron rods set in the rock and fastened there with cement by a diver. They were united together by horizontal rails tied with rope-cord or wire; joists, which were taken away when the day's work was finished, rested upon these rails, which was made use of also as a rest for vertical round-iron posts, which supported plank panels, designed to protect the béton until it had set. The béton was poured in by means of cylindrical boxes, which opened at the bottom to deposit it on the surface, and then closed, so it could be used to spread it out and ram it in place.

Its composition in the interior of the mass varied with the state of the sea; sometimes even pure cement was employed. The béton was never made with less than one part of cement to one of sand, and a similar amount of gravel. The exterior face, to a depth of one meter, had four parts of cement to one of sand. The cement employed in this part of the work set in four or five minutes.

Starting from the level of the sea the work was built of rough rubble masonry laid in cement-mortar, composed, in the lower portion, of equal parts of cement and sand, and in the upper of two parts of sand to one of cement. It was covered with a coating of pure cement-mortar.

This work was commenced in 1858, and was not finished until the end of 1859. The state of the sea was extremely unfavorable during the first year; the scaffolding was carried away, or very much damaged, on several occasions, and a large quantity of the masonry was washed out Thus, for the mass of the foundation, the cost was 215 francs per cubic meter. The masonry above this only cost about 53 francs per cubic meter.

The tower of Cride is established upon a rock, the depth of which below the level of the sea varies from 2.20 to 3.60 meters. The mass of the foundation is octagonal in plan, the diameter of the inscribed circle being 6 meters. The tower itself is four meters in diameter at the base, and 6 meters high. It is crowned by a platform and a balustrade, reached by a ladder fastened to and projecting from the face of the wall.

The plan followed for the construction of this work is very much the same as that we have just described. Vertical uprights of round iron were placed in the angles of the octagon, and a diver made them fast to the rock by means of cement; they were held in place by horizontal braces, the latter being removed after each day's work, as the obstruction they offered to the flow of water endangered the work. The surface of the rock being very unequal between the uprights, the béton could not be at once poured in without much of it being washed away. This surface was made more even around the edge of the polygon by means of a small brick wall, built by a diver under water, and laid in cement. Sheet-piling inserted along the perimeter of the polygon, resting on the brick wall and against the ties connecting the uprights, protected the béton until it had set. The diver was expressly directed to clean off and pick the rock with the greatest care throughout the whole extent of surface covered by the base of the work. He was also directed to press the béton against the sheet-piling, in order to keep it from being washed out

The béton of the foundation was more or less rich in cement as the sea was, or appeared liable to become rough. Above the level of the water the work was built of rough rubble, laid at first in cement-mortar, and afterward in mortar made of the lime of Thiel.

The cost of the masonry of the foundation was 211 francs per cubic meter—117 francs for the masonry laid in cement-mortar and 96 francs for the masonry laid with lime of Thiel.

It is very necessary in works of this kind. to be certain of having a good union between the masonry and the rock upon which it rests, and a system now in use upon our coasts of the Mediterranean is worth describing, because any neglect or imperfection in the work of the diver is remedied by it. It consists in placing three or four vertical cast-iron tubes in the mass of the béton of the foundation, and in making use of them, when this part of the work is finished, to drill holes in the rock, into which strong iron shafts are buried, one half in the rock and the other half in the béton.

This arrangement is represented upon Figures 12 and 13 of Plate 36, which is given as a type of the small beacon-towers on the coasts of the Mediterranean.

When a work of this kind is located upon a point near a port where the sea is not very rough, the balustrade on the summit of the tower is not made use of, as the drawings show. It is sufficient to have handles which persons in the water can take hold of, and several ladders leading up to a resting-place.

Unlighted beacons have the disadvantage of only fulfilling in a very imperfect manner their office at night, and in consequence it has been proposed to indicate their positions by means of bells, the hammers of which are put in motion by the incessant oscillations of the sea. This arrangement has been applied to the tower constructed at the entrance to the port of Rochelle. The mechanism consists of a float, which is raised or lowered in a vertical tube, set in a recess upon the face of the tower, and which, by means of a rod passing through the middle of it, acts upon two bent levers carrying the bell-hammers. It gives very good results, and appears to be susceptible of application at other places. Bell-beacons.

## III. BUOYS.

There is great variety in the forms of buoys, and experience does not seem to have settled the question as to which is best.

All our buoys were formerly made of wood, their dimensions being increased in proportion to the depth of water and the length of the chain by which they were held in place. There are still a great number of these buoys upon several points of our coast. Some have cages or other distinguishing figures on top, and constitute what the English call *beacon-buoys;* others are without them, and are made of various forms. Wooden buoys.

Plate 37 shows the principal types.

Figure 1 represents on one side the section and on the other the elevation, and Figure 2 gives the sectional plan through the line A B of one of the large buoys which are used to mark the entrance to the Gironde. These buoys have a maximum diameter of 2.56 meters and a total length of 7.47 meters. They are moored in water about 19 meters deep at high tide, and maintain themselves at an inclination of about 45 degrees under the joint action of the current and the chains which hold them.

The interior framing is made of oak, with the exception of a central post running through from end to end made of elm ; the mast and staves are of Norway pine. They are surrounded by an oaken girdle near the line of flotation, and are double-coppered below. They are held in place by cast-iron anchors weighing about 1 000 kilogrammes, and chains 0.03 of a meter diameter. They are moored on a sandy bottom. They cost 1 300 francs, not including the chain and anchor.

Figures 3 and 4 give the designs of a kind of buoy which is frequently employed. The buoy which these figures represent, has a diameter of 1.40 meters at the top and is 2 80 meters long. They have an elm post running through them from top to bottom, and their staves are made of Norway pine. They are strapped with iron bands 0.05 of a meter wide, 0.005 of a meter thick. They are arranged in such a manner as to answer the purpose at the same time of a buoy and a mooring for vessels. A bar of round iron 0.03 of a meter diameter runs through its wooden axis for this purpose, and has upon its lower extremity an eye to which the chain is attached, and at the other end a nut, which holds a mooring-ring in place. When the buoy is not intended to fill this double office, an elm base-block generally takes the place of the wooden axis, and the ring to which the anchor-chain is attached is fastened by means of four iron straps, as shown on Figure 7. Figures 5 and 6 represent a small buoy with an elm base-block and iron axis.

These buoys when in place stand at a considerable inclination, and are less plainly visible than beacon-buoys ; but they answer very well in interior channels and have the advantage of being very cheap. They are sometimes made of still smaller dimensions. The buoy shown on Figures 3 and 4 is valued at 500 francs, not including chain and anchor. The chains have a diameter of from 0.018 to 0.024 of a meter ; the anchors weigh from 400 to 500 kilogrammes for sandy bottoms.

The buoy which is represented on Figures 7 and 8 is employed to mark the entrance of Arachon Basin. Ballast is necessary to maintain it in a nearly vertical position when it is not moored in deep water.

Figures 9, 10 and 11 give the plan, elevation, and section of a mooring-buoy for small boats in shallow water. This buoy is square in plan, one meter to the side by 0.80 of a meter high. All the angles are rounded off. The upper and lower surfaces are formed of planks set at right angles to each other, and at an angle of 45 degrees to the intermediate pieces, which are 0.20 of a meter thick, half cut away on both ends, and inclosing a hollow space, which separates the upper and lower planks. This is divided in the middle by a king-post. All the wood used in the construction is Norway pine. The different pieces of the buoy are solidly united by means of bolts and two iron bands. Finally, a strong ring-bolt, 0.05 of a meter diameter, runs through the whole body of the buoy, and is fastened to the mooring-chain by means of a ring at the lower end The mooring-chain is 0.025 of a meter diameter, and the buoy is held in place by means of an anchor the weight of which varies from 300 to 500 kilogrammes, according to circumstances.

Zinc boxes are placed in the open compartments of these buoys in order to prevent the infiltration of water.

A buoy of this kind costs about 200 francs, which includes painting and calking, but does not include the chain and anchor.

Iron buoys.

Plate-iron buoys are more expensive than wooden buoys, at least in their first cost; but they are more durable, their repair is less difficult, and it is easier to give them any variety of form that may be desirable. They are preferable under almost any circumstances.

Buoys of this kind which have been adopted for our coasts have different models. Those most in use are hemispherical on the bottom, conical on the upper part, and are surmounted by a distinguishing mark of some kind.

It is perhaps impossible to determine with any degree of accuracy the most desirable form to give a buoy, because the conditions to be satisfied are very complex, not well defined, and of such variety that it is impossible to have them all in the same formula. However, in the establishment of these aids to navigation, it is well to keep in mind some general considerations, namely: visibility, durability and economy.

The spherical form has been adopted for the submerged part of the buoy, because that figure, for an equal amount of surface, envelops the largest volume, and reduces to a minimum the amount of surface that is submerged. Besides, such a floating body is in a state of stable equilibrium provided its center of gravity is a little below that of the sphere, and it is easy to satisfy this condition by means of properly-arranged ballast. Finally, the spherical form offers less resistance to the action of the waves than almost any other which is likely to be used; and it is easy to have made in any large manufacturing establishment.

The upper part of the buoy is of the form of a truncated cone, and on the summit of the cone is placed a cage, or signal, arranged in various ways. The object of this appendage is to increase the distance at which it is visible, and especially to give the buoy a distinctive character, in addition to those given to it by means of colors and inscriptions.

The buoy is divided into two parts by water-tight partitions, in such a manner that it will not fill when it leaks or is broken by the shock of some floating body. A vertical pipe, closed by a plug, tapped to the upper part of the buoy, allows it to be emptied by means of a pump introduced through it into the lower compartment. Two man-holes are made in the buoy, one on the top and the other in the water-tight partition.

The ring to which the anchor-chain is attached forms a part of the mass of forged iron of which the base of the buoy is made; it has the form of a spherical cap, upon which the iron plates of the lower part are riveted.

The ballast is of cast-iron, and is composed of several movable plates bolted together so as to form a solid mass. It does not weigh more than 750 kilogrammes in the largest buoys. It is reduced, as will presently be noticed, when the depth of water is greater and the current less rapid When it has been properly regulated, the buoy maintains itself sensibly in a vertical position under the ordinary conditions of the sea, and is never inclined more than 45 degrees under the action of the strongest wind and current.

A band or girdle of elm-wood encircles the buoy near the level of the line of flotation. It is designed as a fender, to protect the buoy from the shocks of floating bodies and the rough usage received in transportation.

The forms in most general use for the distinguishing marks of buoys, are the sphere, the cone with a single or double nappe generated with right lines or curves, and rectangles or triangles crossing each other, their surfaces being made of strips set close together or with open spaces between them.

Figures 11 and 12 of Plate 38 represent two specimens of distinguishing marks placed on iron buoys. They are made of plate-iron and set on the axis of the buoy which runs through its whole length.

The buoy which is represented on Figures 1 and 2 of Plate 38 is known in the Light-house Service as an ordinary buoy of the first class. The first of these figures represents a half elevation on one side and a half section on the other; the second is a top view (with the ball removed) on the left, and a sectional plan through the wooden fender on the right. This buoy has a diameter of 2.38 meters, and the body of it is 3.20 meters long. The top of the signal is about 4 meters above the line of flotation.

The iron plates of the lower part have a thickness of 0.009 of a meter; that of the conical part above, as well as the water-tight partition, is reduced to 0.005 of a meter. The ballast is fully shown on the drawings; it weighs 750 kilogrammes, and Figure 3, which represents that of the bell-buoy, shows how it is arranged It places the line of flotation at a height of 1.15 meters above the center of the mooring-ring, or 0.13 of a meter above the lower edge of the wooden fender, when it is moored with 10 meters of chain. This line is lowered 0.01 of a meter by taking off 52 kilogrammes of ballast.

The mooring-chain is made of 0.034 of a meter iron. It weighs 25 kilogrammes per running meter out of the water and about 22 kilogrammes in it. The line of flotation is raised 0.004 of a meter by each additional meter of suspended mooring-chain.

The center of gravity of the buoy with full ballast, but without the chain, is 1.087 meters above the center of the mooring-ring, or 0.278 of a meter below the center of the sphere of which the base is a part.

The mean weight of these buoys is about 2 000 kilogrammes with the shackles, but not including the ballast. They cost nearly 2 000 francs, as follows:

| | Francs. |
|---|---|
| 1 840 kilogrammes of plate-iron at 0.90 of a franc - - | 1 656.00 |
| 750 kilogrammes of cast-iron ballast at 0.25 of a franc - | 187.50 |
| 4.20 kilogrammes of bronze for the collar of the pump and air-tube at 5.50 francs - - - - - - | 23.10 |
| Wooden circular fender - - - - - - - | 40.00 |
| Painting, &c. - - - - - - - - - | 70.00 |
| Total - - - - - - - - | 1 976 60 |

The ordinary buoy of the second class has the same general arrangements and form as the preceding, but is of less dimensions. It is 1.82 meters diameter and the body of it is 2 50 meters long. The top of the signal is 3.30 meters above the mean line of flotation. The iron plates of the spherical part are 0 007 of a meter, and above that 0.004 of a meter thick The entire ballast weighs 150 kilogrammes With 10 meters of chain the line of flotation is at 0.89 of a meter above the center of the mooring-ring, or 0 09 of a meter above the lower edge of the wooden circular fender. This line is lowered 0.01 of a meter by taking off 29.50 kilogrammes of ballast, if it does not go below the lower edge of the fender. The mooring-chain is of 0.030 of a meter iron. It weighs about 20 kilogrammes to the running meter out of the water and 17 kilogrammes when immersed. The line of flotation is raised 0.006 of a meter for each additional meter of mooring-chain that it carries.

The mean weight of these buoys is 1 070 kilogrammes including the shackle, but not the ballast. They cost about 1 000 francs, as follows:

| | Francs. |
|---|---|
| 990 kilogrammes plate-iron at 0.90 of a franc - - - | 891 00 |
| 150 kilogrammes cast-iron ballast at 0.25 of a franc - - | 37.50 |
| 4.20 kilogrammes bronze - - - - - - - - | 23.10 |
| Wood fender - - - - - - - - - - | 30.00 |
| Painting, &c. - - - - - - - - - | 38.40 |
| Total - - - - - - - - - | 1 020.00 |

The buoy represented on Figure 4 of the same plate is employed in cases where it is not necessary that it should be seen at a great distance, and in comparatively shallow water. It has a diameter of 1.50 meters and is 2 meters long; it has no marker or signal on top. It is made of plate-iron, which is 0.006 of a meter thick below and 0.004 of a meter thick above. It has no ballast. The line of flotation is at 0.76 of a meter above the center of the mooring-ring when there are 10 meters of chain attached, and it is raised about 0.005 of a meter for each additional meter of chain suspended, as long as it is kept within proper limits. The chain is made of 0.025 of a meter iron, and weighs 14 kilogrammes per lineal meter out of the water and about 12 kilogrammes in it.

There is a man-hole in the conical part of the buoy, and another in the water-tight partition; the latter is placed on the same level as the circular fender.

One of these buoys weighs 540 kilogrammes, and costs about 500 francs.

Figures 5 and 6 of the same plate represent the bell-buoy in most general use on our coast. It consists of a water-tight vessel surmounted by an iron frame, upon which are fastened longitudinal wooden strips 0.01 of a meter thick, the upper portions of which are covered by a conical cap made of boiler-iron. In the interior of the frame is a bronze bell with movable hammers, and the top of it is crowned by a signal, above which is a triangular prism covered with mirrors The envelope does not extend down to the lower ends of the uprights of the frame, as it is necessary to allow free passage to the waves which break over the buoy. The object of the mirrors, is to reflect the rays of the sun or of a neighboring light. They are set in a bronze frame.

The body of the buoy has a diameter of 2.43 meters and is 1.70 meters high.

The top of the prism of mirrors is about 4 meters above the line of flotation.

The iron plates in the lower part are 0.009 of a meter, and those of the upper part and the water-tight partition are 0.005 of a meter thick. The ballast, which is fully represented on the drawings, should weigh 500 kilogrammes when the length of the mooring-chain does not exceed 10 meters. The line of flotation is then at about 0.12 of a meter above the lower edge of the wooden fender. When the length of the mooring-chain is changed the amount of ballast is also changed in about the same proportion, as in the case of an ordinary first-class buoy.

The mooring-chain is made, as in the case of the first-class buoy, of 0.034 of meter iron.

The mean weight of a buoy of this kind without ballast, but with shackle, is estimated at 2 200 kilogrammes

They cost about 2 300 francs, as follows:

| | Francs. |
|---|---|
| Iron plates, 1 896 kilogrammes at 0.90 of a franc - - | 1 706.40 |
| Cast-iron ballast, 500 kilogrammes at 0.25 of a franc - - | 125.00 |
| Bronze for bell, mirror frames, neck of pump, &c., 54 kilogrammes at 5 50 francs - - - - - - - | 297.00 |
| Wooden circular fender and laths - - - - - | 90 00 |
| Painting, &c. - - - - - - - - - | 81.00 |
| Total - - - - - - - - - | 2 299.40 |

Buoys shaped like a boat have, over those just described, the advantage of offering less resistance to the currents, and can be easily towed to their stations or into port. They have the disadvantage however of being more expensive.

Plate 39 represents a buoy of this kind, which was constructed according to the designs of Engineer M. Leferme, and is now moored at the mouth of the Loire.

The form of the submerged part of the buoy is made to give it stability and as little resistance as possible to the flow of water, and it is provided with a rudder fastened to the bottom, designed to hold it in the direction of the current. The mooring-chain is made fast to the bottom of the buoy just in front of the rudder and near the middle of the boat. This buoy having been constructed for a certain depth of water carries no ballast. It is divided by a water-tight partition. The upper frame-work, the bell, the ball, and mirrors are arranged in a manner similar to that just described for ordinary bell-buoys.

The buoy is moored in 18 meters water at high tide. It has a short-linked mooring chain made of 0 042 of a meter iron; it is held in place by a cast-iron anchor weighing about 1 200 kilogrammes.

The center of gravity of the buoy in still water is 0.41 of a meter above the line of flotation, and the center of the buoyant effort of the water 0.21 of a meter below the same line. The buoy would right itself even though inclined at an angle of 45°, since the meta-center would then be 0.20 of a meter above the center of gravity. The line of flotation indicated on Figures 2 and 3 is that which the buoy takes on a smooth sea and in 18 meters water. The iron plates of the lower part are 0.008 of a meter, those of the upper 0.005 of a meter, and those of the frame 0.0015 of a meter in thickness. The rudder is made of 0.02 of a meter plate-iron. The buoy weighs 4 665 kilogrammes, exclusive of the bell, mirrors, chain, and anchor. It cost at the rate of 1.10 francs per kilogramme, and even then the builder declared that the price did not remunerate him.

A buoy of this kind could be held in place with lighter chains than those here used, and should be, if the depth of water be not too great.

Some wrought-iron buoys of very ingenious construction, the invention of Mr. Herber, of London, were made as an experiment. They are hollowed out at the base, so that the point of fastening of the mooring-chain is very close to the center of gravity. They stand up well, but they have the disadvantage of being very expensive, and offer too great resistance to the upward action of the waves. A continuance of their use does not appear to be justified by experience.

Figure 7 of Plate 38 represents, on one side, a section, and on the other an elevation, of a type of mooring-buoy which is made use of in several of our ports, roadsteads, or anchorage grounds. It is constructed of various dimensions. The buoy taken as an example has a diameter and total height of 1.8 meters. It is made of plate-iron 0.006 of a meter in thickness; the bolt running through it from top to bottom, and to the lower end of which the mooring-chain is attached, is 0 06 of a meter diameter, and the tube through which it passes has a diameter of 0.08 of a meter; it is arranged on the upper end with a mooring-ring nut, which rests on the top, and presses the collar of the lower end of the bolt against the bottom of the buoy. There is no water-tight partition, and the man-hole and plate are fitted on the submerged part of the buoy in order to be protected from injury in transportation. The mooring-chain is short-linked, and made of 0.032 of a meter iron.

The weight of a buoy of this kind is estimated at 775 kilogrammes, and its price 600 francs.

Figure 9 of the same plate represents, on one side, the half-section, and on the other the half-elevation, of a large buoy that the Transatlantic Packet Company of Brazil has had anchored in the Gironde as a mooring for their large ships. It is 2.5 meters diameter, and has a total height of 3.05 meters; it is made of plate-iron 0.006 of a meter thick in the conical part and 0.005 of a meter thick in the rest of it.

The diameter of the mooring-bolt running through the axis of the buoy is 0.06 of a meter; the cylinder through which it passes being of cast-iron and 0.18 of a meter interior diameter, is composed of four pieces having flanges and bolts. The cylindrical part of the buoy is divided into three water-tight compartments by means of horizontal partitions, each of which is held between the flanges of the central tube The plate-iron collars which close the tube at the top and bottom are made in two parts, in such a manner as not to give too much play to the mooring-bolt There is a man-hole with a plate in the upper surface of the buoy, and one in each of the water-tight partitions. Two pump-tubes are inserted from the top and open, one in the lowest compartment and the other in the next one above. All the joints are made water-tight by means of a coating of red lead and mastic.

The mooring-chain is 0.045 of a meter in diameter, and is made fast to a bridle-chain held by two anchors, one at each end, the weight of the anchors being 3 000 kilogrammes.

Manner of mooring.

The system adopted for mooring a buoy depends so much on local circumstances, which vary to such an extent that it is impossible to give any definite rules in regard to it.

So far as the chains are concerned, their size and strength are proportional to the resistance the buoys offer to the flow of water, and to the roughness of the sea where they are moored; but this last consideration is generally neglected, as it would be very difficult to accurately estimate its value; the section of the chain is therefore regulated by the dimensions of the buoy, as has been said in speaking of the various kinds of buoys that have been brought to the notice of the reader It may be added that the chains generally used are always much stronger than, strictly speaking, it would be necessary to have them, because they wear out rapidly, and it is desirable not to be obliged to replace them at too short intervals. The diameter of the round iron of which the links are made is such that the chain may be reduced almost 0.008 of a meter before it would be necessary to substitute new ones.

The wear and tear is not uniform throughout the entire length of the chain; the upper part corrodes generally much more rapidly than the lower, and that part ought to be, therefore, most frequently renewed. This operation is facilitated by having the chain divided into sections, which are united by means of shackles.

These shackles sometimes break open when they are fastened in the usual way, and the buoy goes adrift. These accidents are due to the inefficiency of the keys which hold the bolt in place; the liability to such accidents has been remedied lately by means of a conical iron pin, which runs through the end of the bolt and the two branches of the shackle, the head of which is set in a small dove-tailed cavity, which is afterward filled with molten lead.

All buoys were formerly attached to their mooring-chain by means of an iron swivel. This arrangement, which was one of the weak points of the system, has generally been discarded, there being no sufficient reason for using it, as a floating body having a circular cross-section turns around itself in the water with the greatest facility.

It is admitted, as a rule deduced from long experience, that the mooring-chain of a buoy ought to have a length about three times the depth of the water at high tide. But this is not invariable; it should be more in a place where the waves run to a great height, and less if it be necessary to mark a danger with considerable accuracy, as for example in buoying a narrow channel.

Recourse is had to the bridle mooring in the latter case, such as has already been described in regard to the moorings of floating lights.

Buoy chains are made with short links without studs. They are a little more expensive than the others; but it is known that the studs are apt to come out, and they kink more easily.

Buoy anchors.

Buoy anchors (or sinkers, as they are sometimes called) vary very much, both in regard to form and weight.

Upon a sandy bottom, recourse is generally had to cast-iron anchors similar to those represented by Figures 12, 13, 14 and 15 of Plate 37. Sometimes the eye to which the chain is made fast is made of cast-iron, as is shown on Figure 13; in other cases it is of wrought-iron, and is partly buried in the cast-iron itself when in a melted state; the latter is preferable. The weight of the anchor varies, according to local circumstances and the dimensions of the buoy, from 400 to 1 200 kilogrammes. The same kind of anchor has been successfully employed upon rocky bottoms swept over by stormy currents, but in this case the weight has been considerably increased. It is necessary to use anchors weighing 3 000 kilogrammes for the buoys of the great roadstead of Havre.

The English mushroom anchor, which is represented by Figure 10, Plate 38, is a much better form than the simple flat iron shell, and need not be so heavy. It acts in the same manner as an ordinary anchor when it takes hold in the ground. It has been made use of at several places on our coast.

Old and condemned anchors are frequently employed for the purpose of mooring buoys. One of the flukes is cut off or tied down upon the shank. when the bridle is not made use of, to prevent the chain fouling. The weight of these anchors varies, according to circumstances, from 300 to 1 000 kilogrammes.

Bridle moorings with two anchors is recommended for rocky bottoms, and for places where the currents are strong. They have been used at several places on our coast, and among others in the Four Channel, at the entrance to the harbor of Brest. The buoy anchors at this place weigh about 600 kilogrammes, and the chain connecting them is about 90 meters long. It is 0.030 of a meter in cross-section and has studded links.

The majority of mooring-buoys are held in place by means of two anchors and a bridle; but recourse is sometimes had to other systems. Mitchell's screw mooring is made use of with advantage on sandy or compact clay bottoms. In the harbor of Saint Nazaire, the bottom of which is a sort of natural concrete, overlaid by a thin layer of sand deposited by the river, and where it is necessary to avoid projections of any kind on the surface, a very flat cast-iron anchor, like that represented by Figure 7, Plate 38, is used A section of such an anchor is represented by Figure 8 of the same plate. These anchors are circular in plan, saucer-shaped underneath, and adhere so well to the bottoms, though generally covered with not more than 0.20 of a meter of sand, that in order to take them up to change their location it is necessary to take hold of them by one of the lateral rings. Their weight is estimated at 5 350 kilogrammes The mooring-chain is made fast to the central ring.

## IV. COLOR OF BUOYS AND DAY BEACONS.

We have seen, from what has already been said, that day-marks should be painted of some dark color when they are projected on the sky, and of a light color when projected on a background of earth or foliage Black and white are the two colors in most general use for this purpose; but they are not used exclusively, the necessity of giving to them distinguishing characteristics sometimes necessitating the use of other colors, painting all over of the same color, or in several different colors.

The coloring of day beacons and buoys is regulated by law

All those that the mariner should leave on the starboard hand in coming in from sea are colored red, with a white band immediately below the top; those which he should leave on the port hand are painted black; those which may be left on either side are painted in horizontal bands, alternately red and black. This method of coloring beacons is applicable only to that portion of them which is above the level of high tide; below this level they are painted white.

These colors may be uniform over the buoy, or divided up to form various designs on a white ground, such as square or lozenge-shaped checkers horizontal bands or vertical stripes, in such a manner as to prevent one from being mistaken for another.

The appendages of buoys are painted white.

Upon each buoy or beacon is written, sometimes entire, sometimes abbreviated, the name of the shoal or danger that it marks, and a regular order of numbers is given to those that belong to the same channel.

These numbers commence with the outermost.

Even numbers are given to those beacons or buoys that the mariner, coming in from sea, leaves on the starboard hand—that is, those that are painted red; and odd numbers are given to those left on the other side, viz, the black.

Those beacons or buoys painted with black and red bands or stripes have their names on them, but no numbers.

The small points of rock situated in frequented channels may be painted in the same manner as day beacons, with this difference—that it is only necessary to paint the part that is most easily seen, where they have a larger surface exposed than is required to render them plainly visible.

# CHAPTER II.

## SIGNALS.

### I. TIDE SIGNALS.

Tide signals are established at the entrances to the greater number of our ports on the English Channel and the Atlantic Ocean. They are made by means of balls and flags, which are hoisted on a frame composed of a mast and yard shaped like a tall cross.

A ball placed at the intersection of the mast and yard indicates that 3 meters depth of water can be carried the entire length of the channel. Each ball placed on the mast, but below the former, adds one meter to this depth; placed above, it adds 2 meters. Hoisted at the end of the yard, one ball represents 0.25 of a meter additional when seen by the mariner on his left, 0.50 of a meter when seen on his right, and 0.75 of a meter additional when both are seen.

In order to signalize the rising or falling of the tide, a white flag having a black cross and a black flag of the form of a pennant are made use of. These flags are raised as soon as there is a depth of 2 meters in the channel, and are lowered as soon as the water falls below this level. While the tide is on the flood the black pennant is above the flag with the cross; as soon as the tide is full, the pennant is lowered and remains down while the tide is on the stand; the pennant is set below the flag during the time of ebb tide.

The annexed plate indicates how these signals are made. It is seen from this that five balls are sufficient to indicate to quarter meters all the depths from 3 to 8.75 meters, and six to indicate in the same way the depths from 3 to 9.75 meters. The flag enables these signals to start with 2 meters depth.

When the tide is too low for vessels to attempt the entrance of a port, all these signals are replaced by a red flag hoisted at the top of the mast.

It is proper to remark that signals as complete as these are not necessary, nor are they used at all sea-ports.

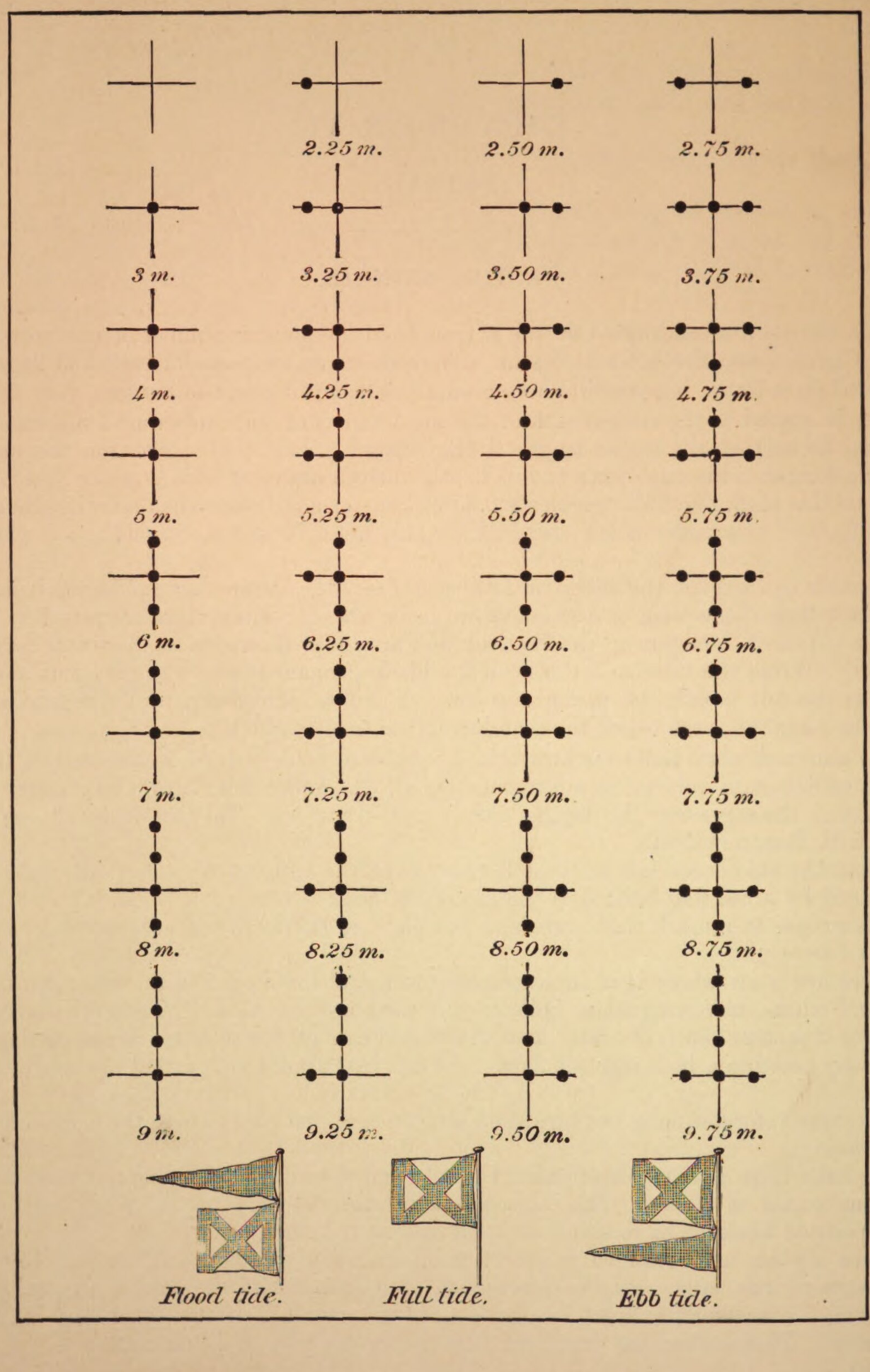
There are ports where it is only necessary to signal the height of the tide from meter to meter, and where, in consequence, balls on the yard are not used. In others it is sufficient to indicate 2 meters depth of water and the movements of the tides by means of flags, then 3 meters by hoisting a ball over the flags. In this case a yard is not used in connection with the mast.

The same information is not furnished at all places, but everywhere the signals have the same meaning.

The balls have a diameter of about 1 meter, and they ought to be kept at least 3 meters apart from center to center. They are generally made of cord netting with small meshes, and are painted black so as to stand out well against the sky.

These signals are arranged in such a manner as to be made use of at night by substituting lights for the balls. At the intersection of the mast with the yard, the initial point of the system, a characteristic light is placed—red for instance, if the others are white, and reciprocally. This system has just been adopted for the port of Dunkerque.

# TIDE SIGNALS.



If it be desired to signal the state of the tide, as is done during the day, the light is colored in various ways, according as it is intended to show a rising or falling tide. It is probable that night signals will not require subdivisions of a meter to be indicated, so that four lights will be sufficient to indicate the full numbers from 3 to 9 inclusive; five would enable it to be carried to 11 meters. This would be a greater depth than the exigencies of actual navigation demand.

## II. FOG SIGNALS.

The proper kind of signals to be made in foggy and thick weather, in order to indicate to mariners the entrance of a port, or the position of a danger, has been the subject of a great deal of study; but the questions that arise have not yet been satisfactorily answered.

The entrances to the greater number of our sea-ports are marked in such states of the weather by bells, which are rung by clappers in the ordinary way, at intervals which vary from one place to another, and some isolated light-houses are also furnished with apparatus of this kind. In the United States of America, where fogs are more frequent than upon our coast, they have spared no expense in investigating the best means of producing sound that can be heard the greatest distance, and there have been established upon several points of the coast, bells weighing as much as 500 kilogrammes, and even more; and upon others powerful whistles blown by means of compressed air.

Some experiments were made in 1854, by the Engineers of the Light-house Service, upon the various instruments that promised to give good results. It may be well to give a summary of them.

Various instruments.

The disadvantages attending not only the use, but also the keeping of supplies for fire-arms, have caused them to be discarded; the various other apparatus successively tried or experimented with, were bells, gongs, tam-tams, (a kind of wooden rattle in use in the East.) metallic plates, trumpets and whistles. Bells, whistles and trumpets were at once found to be superior to all others. However, among the others there were some which produced at a short distance a very marked impression on the auditory nerve. Tam-tams, which are employed on most of the English light-ships, may be cited especially. These can scarcely be heard more than 500 meters, but they have the advantage of producing a very characteristic sound and that recommends their use. A trumpet, made by M. Darche, an experienced musical instrument maker, can be heard a greater distance than any of the other instruments. It is terminated by a paraboloidal shaped mouth, and is provided with a reed valve that is held in place by a spiral spring against the opening through which the air passes, and which vibrates under the double action of this spring and the elastic force of the gas. Its sound has been heard at a distance of more than 2 kilometers, and against a strong breeze, while a bell of 100 kilogrammes could not be heard more than 700 meters.

But the distance at which the sound of this instrument can be heard, diminishes in proportion as we go out of the direction in which it points, and if it be necessary that it should be heard over a large arc of the horizon, there should, in calm weather, be given to it a motion of rotation around a vertical axis, in such a manner that the line of the greatest sonorous intensity may point in all directions successively.

Steam whistles, like those used on locomotives, can not be heard as far as this trumpet; as an offset to this, the sound is uniformly distributed over the horizon; if, however, it be thought unnecessary to distribute the sound in this way, it is probable that by means of a properly established reflector the range of sound can be increased in such a manner as to give as loud a sound as the trumpet, and perhaps louder. Will not the sound produced by the whistle be confounded with the noise of the wind in the rigging? Would not the trumpet be regarded as much more characteristic in its tone? These questions can only be solved by repeated experiments on the water. Besides this, the use of these instruments is attended with the great disadvantage of requiring air compressed to several atmospheres, and of

consuming such a quantity when they are to give a sound at short intervals, that it becomes necessary to have recourse to machinery in order to supply them.

The expense necessarily incurred in the establishment and maintenance of these machines is so great, and inasmuch as the coastwise commerce does not require that fog-signals should be heard at so great a distance, it is not thought advisable to incur the expense of establishing them.

## BELLS.

There remains then the use of bells, and that gives rise to the following questions:

At what distance can bells of various sizes be heard, taking into consideration the direction and force of the wind?

What are the best arrangements to be made in order to increase the distance at which they can be heard?

What is the best means of ringing a bell to render the signal characteristic and prevent its being confounded with sounds produced by other bells?

What is the best method of establishing them in the majority of cases?

So far as the distances at which they can be heard are concerned, some observations have been made in the ports of Cherbourg and Boulogne. They have established as a fact, that sound obtained by the stroke of a hammer upon the bell is heard at a greater distance than when it is rung in the ordinary way by a clapper, and greater still in proportion as the blows (retaining their distinctness) are more rapid. Thus the range is increased in the proportion of 1 to 1.14 when the number, which was 15 per minute was increased to 25 per minute. It is well known that without breaking a 100 kilogramme bell, it may be struck with a 5 kilogramme hammer, falling 0 20 of a meter; and a 200 kilogramme bell may be struck with a 9 kilogramme hammer, falling the same height, without breaking it.

From several experiments, we may conclude that a 100 kilogramme bell, properly established, thus put into operation, can be heard in what mariners call a good breeze at a distance of 1 200 meters against the wind, at about 2 000 meters when the wind blows across, and about 4 000 meters when it blows in the direction in which the sound travels. In a calm or a light cross-wind the distance at which a bell of this kind can be heard is estimated at 2 500 meters. No experiments have been made when the wind was blowing strong; but it is known, that when the wind is blowing in the direction against which the sound is traveling, it can only be heard a short distance. It is also known that fogs are not produced, as a general rule, under such atmospheric conditions; they generally come from the sea, and are wafted in by a light breeze.

The range is increased with the weight of the bell, and, up to a certain point, with the pitch. In order that the strokes, which are to be heard in succession, may be counted without difficulty, there ought to be an interval between them of at least one second; the intervals intended to mark groups of sounds ought not to be less than six seconds.

Two means can be made use of to increase the range of a sonorous instrument. We may have recourse to apparatus to reinforce the sound itself, or we may return, by means of reflection, the undulations which would otherwise be lost by being transmitted in a direction where they would be of no use. The first has been tried without producing the effects hoped for, or at least without benefits commensurate with the expense. Neither a reinforcing tube, nor a large wooden deflector, arranged somewhat like a sideral apparatus, in such a manner as to act at the same time by vibration and reflection, have given any decidedly better results, and the experiments, which were long and expensive, were discontinued. It is probable that more skillful experiments may succeed better; we have abandoned the system without condemning it.

Simple reflection has given a very decided increase in the distance at which sound can be heard. Sound was treated as light; a bell was placed in the focus of a large parabolic or rather hemispherical reflector (because a certain amount of divergence is necessary) made

of material that does not vibrate easily. This apparatus, having an opening of 1.50 meters, was made of an iron shell, enveloped in a bed of Portland cement, from 0.06 to 0.08 of a meter in thickness. The hammers of the bell were operated by machinery. The experiments were made in 1861 and 1862, in the port of Boulogne, by Engineers Messrs. Legros and St. Ange Allard. The bell, with the reflector, was established upon the extremity of the west jetty, and another bell exactly like it, to be used in comparison, was placed immediately above it. They weighed 100 kilogrammes each, produced sensibly the same sound, and were struck at first by hammers weighing about 2 50 kilogrammes, then by hammers weighing 5 kilogrammes, falling 0 20 of a meter, which were raised immediately after the blow by springs. The two bells were put in operation successively, and observers in a boat, proceeding to different points embraced in an arc of the horizon of 180° made known by means of a flag the moment when they no longer heard the sounds. Two observers, properly stationed on shore, determined the positions accurately. These points were afterward plotted on a map, and were sufficiently numerous to allow the curve of the range of each experiment to be traced with all the accuracy that the subject demanded; afterward lines were drawn through each angular space of 9° on each side of the axis of the reflector, so that we were able to make a comparative estimate of the range in each direction.

The experiments were made under various circumstances of intensity and direction of the wind.

If they had been made during a period of perfectly calm weather the curve of the ranges of the isolated bell would have been an arc of a circle, with slight modifications produced by the position of the hammer, and the other would have been more or less elongated in the direction of the axis of the reflector and drawn in on the sides. But the wind had the effect of deforming these curves in proportion as it was stronger, and it gave the maximum intensity of the bell with a reflector pretty nearly the same direction as that of the other. The reflector always increased the off-shore range, but not in the prolongation of its axis. The reflected sonorous vibrations were carried very much in the same direction as the others, so that, except in calm weather, there would be no real advantage in giving the reflector a movement of rotation around the horizontal plane, which was contrary to what several persons expected. We could not thus make the longest range reach successively every point of the horizon.

The summary of the experiments, seven in number, and complete enough to allow a tracing with sufficient exactness of the curves of which we have spoken, established the fact, that the mean proportion of the range of the isolated bell to that of the bell with a reflector was as 100 to 147 in the angular space of 60°, where the sound was heard farthest, and that the isolated bell had the advantage only at more than 100° from the line of greatest range. It was also determined that calm weather, or the wind in the direction in which the sound moves, increases the comparative value of the bell with the reflector. The mean proportion of maximum ranges in the two cases was almost as 10 to 17; while the second term of this proportion is decreased to 13 with a strong wind blowing against the direction of the sound.*

These facts being established, it may be a question whether an increase in the weight of the bell would not give, at less expense, results equivalent to those with the reflectors, and a new series of experiments was made in which two bells were compared, one, 100 kilogrammes in weight, with a reflector, and the other, 225 kilogrammes, entirely isolated. The hammers of the bells fell 0 20 of a meter and gave 60 strokes per minute; that of the first weighed 5 and that of the second 9 kilogrammes. The greatest range of the large bell was 6 140 meters, and that of the other was 7 625 meters, with a strong breeze blowing toward the observers. In an angular space of 60°, comprising the maxima ranges, the mean proportion deduced from all the observations was in favor of the bell with the reflector, but only

* For extended investigations in regard to phenomena attending the transmission of sound through the air, see Appendices to Reports of Light-House Board, 1874 and 1875.—P. C. H.

as 128 is to 100; and this proportion was sensibly the same for the total of the observations which were carried through an angular space of 115°.

A much larger bell would have been necessary to have gained on the reflector in the direction in which it was desired to transmit the sound; so that the economical value of this apparatus is indisputable. All its applications will be restricted by a regard to the small space that is generally disposable either upon the heads of jetties or upon the galleries of light-houses.

Distinctions.

Particular distinctions have been adopted in sounding the bells, in order to prevent mistakes. The strokes of a bell, made with a very simple machine, are arranged in groups, which comprise a certain number of blows succeeding each other at regular intervals, and are separated by intervals of silence. Thus a sound of 6, 8, or 10 blows, struck at intervals of 2, 3, or 4 seconds, is followed by a silence of 15 or 20 seconds. Then they are repeated. In sea-ports the minimum depth of water in the channel is indicated by adding a single or double blow at the middle of the interval which separates the groups.

It is better, so far as the range is concerned, to have the blows succeed each other as rapidly as possible, and at the same time remain distinct; but it is a disadvantage so far as the machinery is concerned, requiring it to perform a greater amount of work, and to be more frequently wound up.

The number of blows being much easier to distinguish than the duration of the intervals, it is *that* which gives it its characteristic, and it is easy to understand that this system is susceptible of more diversity than can be given to illuminating apparatus.

## CHAPTER III.

### LIST OF BEACONS AND BUOYS ON THE COASTS OF FRANCE,

JANUARY 1, 1864. OMITTED.

# DOCUMENTS.

SIGILLUM
DOGANIENSIS

II.

# MEMOIR

UPON A

# NEW SYSTEM OF LIGHT-HOUSE ILLUMINATION,

BY

AUGUSTIN FRESNEL.

---

READ BEFORE THE ACADEMY OF SCIENCES, JULY 29, 1822.

---

There has existed for several years a Commission of Lights, the members of which were chosen from among the most distinguished scientists and the Inspectors of the Royal Corps of Engineers des Ponts et Chaussées. Charged with devising a general project for the distribution of light-houses upon the coasts of France, they sought at first to determine whether the system of illumination already in use could not be improved. Several interesting experiments had already been made upon the brilliancy of the light produced by small wicks placed in large Lenoir reflectors; but other duties, with which a majority of them were charged, prevented them from devoting the necessary time to these investigations. In 1819 M. Arago offered to take charge of these experiments, provided M. Mathieu and myself were allowed to assist him. This proposition, adopted by the Commission, was submitted to M. Becquey, Director General des Pouts et Chaussées, who also approved it, and desired me to devote the greatest care to these investigations. A wish to be worthy of his confidence, and of that of the Commission of Lights, as well as the importance of the subject, induced me to devote all my attention to these investigations.

From the very first I thought of substituting large glass lenses for the parabolic reflectors. We know that, like a parabolic mirror, a lens has the property of parallelizing the rays of light that issue from its focus and pass through it; it produces, by refraction, the same effect that a parabolic mirror does by reflection. This application of lenses to light-house illumination could scarcely be regarded as a new idea; it would readily occur to any one, and there is, indeed, now in England such a lenticular apparatus, but it appears that it gives very little light, which is probably due to the great thickness of the lenses employed, (0.20 of a meter,) and perhaps also to the general arrangement of the apparatus, upon which point I have no very precise information.

NOTE.—Documents I, III, IV, V and VI are omitted in this translation.—P. C. H.

If the thickness of the lens does not exceed the ordinary thickness of plate-glass, the amount of light absorbed by it will be very small as compared with that which passes through; the loss resulting from partial reflection on the two surfaces is only one-twentieth, according to the experiments of Bouguer; but even supposing it to be one-twelfth, it is readily seen how little the light will be reduced in intensity by its passage through such lenses, and what advantages they would have in this respect over the best metallic reflectors, which absorb one-half of the light when the angles of incidence are slightly oblique, as is always the case with the greater portion of rays, in a parabolic mirror. This consideration led me to hope that I could economise the light considerably by substituting lenses for parabolic mirrors.

Some transparent liquids, such as water and spirits of wine, absorb only a small portion of the light that passes through them, even though the thickness be 0 20 or 0.30 of a meter; and it might be supposed that large lenses made by inclosing a liquid between two shells of glass might be used in light-houses; but, besides the great weight of such lenses, which would tend to rapidly wear out the machinery which gives a rotary motion to the apparatus of eclipse lights, the long continuance of these liquids in the cases would cause the interior to become tarnished, and it would be very difficult to clean them. The mastic used for uniting them might crumble away at some points along the edges and allow the liquid to escape. It was, therefore, much better to avoid these difficulties by employing solid materials.

It was also necessary, in order to avoid too great a loss of the rays emitted by the light placed at the focus, that each lens should embrace all the rays included in an angle of 45°, and it then follows that the prismatic angle of the glass at the edge of the lens should be 40°. It will readily be seen that the glass at the center would be very thick if the lens were terminated on the outside by a continuous spherical surface. This great thickness would have the double disadvantage of very much reducing the intensity of the light passing through it and of rendering the lens entirely too heavy.

But if the exterior surface of the lens be divided into concentric rings, and if, from the small lens in the center and the rings which surround it, all the useless portion of their thickness be removed, leaving only enough to permit of their being solidly united at their thinnest edges, the parallelism of the rays emerging from the focus can also be obtained, or, what is the same thing, rays parallel to the axis of the lens and falling on the outside, can be united at the focus by giving to the surface of each ring the proper inclination and curvature.

Buffon was the first to suggest echelon lenses for increasing the power of burning-glasses while diminishing their thickness; but, from what he said on this subject, it is evident that he proposed to make them of a single piece of glass, which would render their fabrication almost impossible, especially when of large dimensions, on account of the difficulty of cutting away the glass and smoothing and polishing the surface where such projecting edges are presented. He expresses himself in regard to it as follows:

"I then endeavored to devise some means of overcoming this difficulty, [that of the too great thickness of the glass,] and I found a simple and easy manner of diminishing the thickness of the lenses to any desirable extent without sensibly diminishing their diameter and without lengthening their focal distance.

"This consists in cutting my piece of glass into steps. In order to make myself better understood, let us suppose that I wish to diminish to *one inch* the thickness of a glass lens which is twenty-six inches in diameter, has five feet focal distance, and is three inches thick at the center. I divide the exterior curved surface of the lens into three parts, and move each of these parts toward the center of curvature until there remains but the thickness of one inch in the center of the lens, a step being formed on each side by moving the corresponding parts an equal amount. Then, by making a second step, I reach the extremities of the diameter, and have a lens in steps, (à échelons,) which has about the same focal distance, the same diameter, and is only about one-third as thick as it was at first, which is a great advantage.

"If a piece of glass *four feet in diameter by two and one-half inches thick* be first molded and cut into steps (échelons) for a focal distance of eight feet, I have estimated that, leaving it even one and one-half inches thick at the center of the lens and the same at the interior edges of the steps, the heat from it [used as a burning-glass] will be to that of the Palais Royal lens, as 28 is to 6, without taking into account the effect due to the difference of thickness, which is very considerable, and which I cannot estimate in advance.

"This kind of refracting mirror is in every respect the most perfect of its kind; and even if we reduce its diameter to three feet and its thickness to fifteen lines* at the center, and six feet focal distance, which will render its fabrication much less difficult, a degree of heat can be produced which is at least four times as great as that of the most powerful lenses known. I dare say that this échelon mirror would be one of the most useful instruments in physics. *I invented it more than twenty-five years ago*, and all scientists with whom I have spoken about it desire that it should be made. It will be of great service in the advancement of science; and applying a heliometer to it we could conduct at its focus all chemical operations as easily as in the fire of a furnace," &c.

This quotation sufficiently proves that Buffon had not thought of constructing his lenses in several pieces, since he made their construction depend upon the casting of a piece of glass *four feet in diameter by two and one-half inches in thickness*, which he proposed afterward to reduce to *three feet in diameter by fifteen lines in thickness, in order to render its fabrication more easy*. Now, by making these lenses in several pieces, it is as easy to construct one of four feet in diameter as of three feet, even if the focal distance be much shorter than Buffon supposed. It is easily understood why, twenty-five years after having invented these lenses, and notwithstanding his earnest desire to possess one, the same scholar who invented the beautiful mirror of Archimides, the construction of which was much more complicated and much more expensive, was unable to procure an échelon lens three feet in diameter; it was because he had not thought of making them of several pieces.

Moreover he did not, apparently, perceive a great advantage offered by the separate fabrication of each ring, namely, the almost complete correction of spherical aberration by using a sufficient number of rings and generating their exterior surfaces by arcs having proper radii of curvature; because, after considering the original lens as terminated by a continuous spherical surface, he proposes that it be depressed in steps, but so that the portions of the new spherical surfaces should be concentric with the first, which is not the true way of correcting spherical aberration. We find, by calculation, that the generating arcs of the rings not only ought not to have the same center, but that their different centers should not be situated upon the axis of the lens, and that they depart from it in proportion as the arcs to which they belong are more distant from the center of the lens; so that these arcs on being revolved about the axis do not generate portions of concentric spherical surfaces, but surfaces of the kind known to geometricians as annular surfaces.

It may seem strange, perhaps, that I dwell at such length on these simple reflections. It is undoubtedly very easy to imagine lenses composed of several pieces, and to deduce from the ordinary laws of refraction the most suitable form for the surface of each ring. But it is also easy to invent lenses with steps, as I know from my own experience, because I did not know what Buffon had published upon the subject when I proposed for the first time to the Commission of Lights the construction of such apparatus. It was M. Charles who informed me that this invention was not new, and he showed me the chapter of the supplement to the Natural History where it is described. Having thus lost a part of what I had invented, I may be excused for showing some solicitude for the preservation of the little that is left me, especially when it is precisely that which renders the invention practicable on a large scale.

These ideas—of the lens in steps and of forming it of separate pieces—were not the fruit of long study; they are so simple that they readily occur to the mind. What occupied

* A line is equal to 0.09113 of an inch.

me most was the means of executing them; in this I have been ably seconded by the zeal and intelligence of M Soleil, the optician, who bravely undertook the construction of these large lenses.

As only spherical surfaces can be made by the ordinary process in basins, I first divided each ring into a sufficient number of pieces, and then calculated the curvature and the inclination of the small portion of a spherical surface that I substituted for the corresponding part of the annular surface, in such a manner that the spherical aberration would be the least possible. These calculations were longer and more tedious than those which would be required for determining the elements of annular surfaces. I hoped to afterward make the latter, but in order to have, as soon as possible, a large lens with which to make experiments as to its adaptibility to light-house illumination, it was necessary to employ the means that M. Soleil had at his disposal. That determined me to substitute, for the time being, for each annular surface an assemblage of small portions of spherical surfaces, and even to give to the rings the form of a polygon, instead of a circle, as it was more easy to work pieces of the glass in straight lines.

In order to unite all the pieces which compose the lens, I thought at first of fastening them upon plate-glass by means of thickened Venetian turpentine, which M Cauchois had employed with success in gluing the object glasses of a telescope, and which was not likely to become spotted as soon as drop mastic. But experience has shown that the heat of the sun would melt it and cause it to run at the joints. Strictly speaking, I might have been able to prevent this by closing the joints with cement. Nevertheless, it appeared preferable to fasten the pieces of glass to each other at their edges by means of a strong glue, because, in this manner, the transparency of the lens would be wholly independent of any changes in the material with which they were united. In the place of Flanders glue, we employed, after consultation with M Arago, fish glue; its strong adherence to glass being well known to him, as he had vainly endeavored to separate, in boiling water, two prisms which had been united by it. It was not because glue of ordinary strength does not adhere sufficiently to the glass; in fact, it sometimes happens that, when removed without proper care, it carries with it small splinters of the glass; but fish glue, which probably possesses this quality to a higher degree still, has the advantage of being clearer and less brittle.

In place of making the pieces of glass composing the lens curved on both sides, that is, making them double convex, I made them plano-convex, in order to simplify the making and render easier the cementing of the edges; they can then be placed flat side down upon a marble table covered with a sheet of paper, and be left there for any length of time necessary for the glue to dry. On the other hand it would be difficult to unite by the edges a large number of pieces of glass of the double-convex form.

Following out the process that I have just described, M Soleil succeeded easily in constructing a large square lens 0 76 of a meter on the side, its form and dimensions having been determined so that it could be made a part of an illuminating apparatus which I had devised, and which would greatly surpass the luster of the most brilliant light-houses; as M. Arago, M. Mathieu, and myself were convinced from our preliminary experiments upon a smaller lens only 0.55 of a meter square.

As soon as experiments had demonstrated to the Commission of Lights the advantage of the new system of illumination, M. Becquey, after having assured himself of the superiority of the large lens over parabolic mirrors, ordered the construction of an apparatus composed of eight such lenses. I engaged M. Soleil to try to make one with annular surfaces instead of composing each ring of small portions of spherical surfaces. I attached great importance to this improvement, not only for light-houses, but also for burning-glasses, in which it is still more essential to completely correct the effects of spherical aberration. At that time I indicated to M. Soleil the mechanical process that he has since definitely adopted, and which he now employs with so much success.

In the execution of lenses designed for the illumination of light-houses, it is not necessary to attain a very high degree of accuracy, but, nevertheless, the substitution of annular surfaces for the assemblage of small portions of spherical surfaces produces a sensible increase in the light thrown out in the direction of the axis. Besides, the mechanical process by which annular surfaces are formed allows the construction of large lenses with much greater rapidity, than when we were obliged to work separately in the basins, the ninety-seven pieces of which each polygonal lens was composed. The number could not have been diminished without increasing at the same time the spherical aberration, whilst, in the annular lenses, there is no disadvantage in diminishing the number of pieces which compose each ring; in fact, there would even be an advantage in making it of a single piece, provided it could be done, because the multiplicity of these divisions always causes a small loss of light, and is less favorable to the solidity of the apparatus. On account of these considerations, presented by M. de Rossel and M. Arago, M. Becquey ordered, last year, the construction of eight annular lenses designed for the illumination of the Cordouan light-house, in order to encourage this new branch of industry, and that M. Soleil might be induced to have the necessary machinery constructed.

The grinding of the rings has become much less tedious since this optician, in place of being obliged to rework his pieces of glass, receives from the manufactory of St. Gobain large arcs run in molds, the forms of which more nearly approach their finished condition, than did the pieces reworked by him

This favor was kindly accorded to M. Soleil by the manufacturers, at the request of the Commission of Lights, and the accomplished Director of the establishment, M. Tassaert, has taken great interest in the successful casting of our curved prisms. Nevertheless, they are not as free from striæ, and especially from bubbles, as plate-glass carefully remolded. It appears that when pieces of cast-glass are more than eighteen inches in length and two or three inches thick, it is very difficult to preserve them entirely free from bubbles and spots. Flint-glass, or glass with lead in it, is less liable to bubbles, but it has the disadvantage of being more liable to striæ; besides, it is much heavier than the crown-glass of St. Gobain; it is principally for the last reason that we prefer the latter, notwithstanding its decided greenish tinge; besides, the latter is harder and less liable to be affected by the air than glass in which there is much oxide of lead.

Our large lenses, 0.76 of a meter square, which subtend at the focus both horizontally and vertically an angle of 45°, show on the outside, from the center to the middle of either side, six steps or échelons, including the center lens; and ten steps or échelons from the center to either corner; and the most salient ring has only a maximum thickness of 0.037 of a meter;* and the weight of the lens, including a strong copper frame, does not exceed 75 pounds. In order not to load too heavily the machinery by which rotary motion is given to an apparatus composed of eight lenses, it was necessary to reduce the weight as much as possible by increasing the number of steps. The width of the rings was determined so that their projecting angles should vary as little as possible.

Having described the construction of these large lenses, I propose now to explain how they are arranged in the apparatus, which is to serve for the illumination of light-houses. Of all the combinations of lights, of lenses, and reflectors that I have thought of, the following appears to possess superior advantages. All the light intended for the illumination of a light-house is united in one single flame this flame is surrounded by eight square lenses set vertically, the centers of which are situated in the same horizontal plane as the single light, their distance from the flame being equal to the focal distance of parallel rays; they thus form around the brilliant object a vertical prism having a regular octagonal base; and, as each embraces an angle of 45° in a horizontal and vertical direction, they receive and transmit the luminous rays comprised in an equatorial zone of 45°, belonging to a sphere which has its center at the common focus of these lenses. Now this zone comprises 0.383 of the surface of

* The angle pieces are not thicker than 0.04 of a meter.

the sphere, or about two-fifths; and if we suppose that the intensity of the light is diminished one-tenth by its passage through the lenses, there will still remain 0.34, that is to say about one-third. It is probable that the loss of light may be a little more, but, on the other hand, the lower part of the luminous sphere receiving much less light than the rest on account of the opacity of the lamp-burner which holds the wicks, the equatorial zone of 45° will actually contain more than two-fifths of the total light emitted; thus there is undoubtedly no exaggeration in estimating the total amount of light refracted by the lenses at one-third the total emitted.

Reflectors have the advantage of enveloping, so to speak, the brilliant object, and of receiving a larger number of rays; but they absorb at least one-half. Parabolic reflectors embrace ordinarily. about seven-tenths of the total surface of the luminous sphere; but this fraction should be reduced to six-tenths on account of the burner, which intercepts many rays in the lower part of the reflector. Consequently one-half of the light being absorbed by the mirror, the sum of the rays that it reflects is equal to three-tenths of those emanating from the focus—in other words, a little less than the sum of the rays transmitted by the lenses.

The useful effect of the lenses and the reflectors does not depend alone upon the proportion of the refracted or reflected rays, but on their greater or less concentration in the horizontal plane where the light will be useful to mariners; this depends upon the relation between the dimensions of the brilliant object and the distance from the focus to the various points on the surface of the mirror or lens. In the lenticular apparatus that I have just described this distance varies but little; it is 0.92 of a meter from the center of the lenses, one meter to the middle of their edges, and 1.07 meters to their angles. In a parabolic reflector, on the contrary, the distance from the focus to the various points of the surface varies from one to three and one-half; and to the extremity of the parameter it is double what it is to the summit of the paraboloid. In the largest reflectors yet employed, which have an opening of thirty-one inches and weigh nearly one hundred pounds, the distance from the focus to the summit of the paraboloid is only 5 inches. The vertical divergence of the rays in that half of the luminous sphere nearest the summit will, it is seen, be great, even when the flame which illuminates it is only one and one-half inches in height. A part of these diverging rays are, without doubt, usefully employed in illuminating the vicinity of the light-house; but the rays which pass out above the horizontal plane are absolutely of no use whatever. As the intensity of the light decreases proportionately to the square of the distance, it is to the most distant points of the horizon that the greater portion of the rays should be directed; and it is not necessary to reserve much of the light to illuminate the near vicinity of the light-house

It is, therefore, by the sum of the rays directed in a horizontal plane that the comparative effects of illuminating apparatus for a light-house should be judged; and it is in this respect that M. Arago, M. Mathieu, and myself have compared the useful effects of reflectors and large lenses.

It would be very disadvantageous if the central light in lenticular apparatus was formed by an assemblage of a large number of ordinary Argand burners; because if they were only ten in number the loss of light from each, due to the interception of rays by the others, would be considerable. The intensity of the light being the most essential quality in a light-house, it was necessary, in order to make the most advantageous use of the lenticular apparatus, to produce a central light of great brilliancy and of small dimensions. M. Arago and myself have succeeded in solving this problem in a satisfactory manner by carrying out the idea of M. Rumford in regard to multiple wicks; and we have been even more successful in our trials than he was. We have had constructed burners with two, three, and even four concentric wicks, which can be managed almost as easily as an ordinary burner. We have completely succeeded in protecting the burner from the great heat developed by causing an overflow of oil, as is done in the Carcel lamps; and this arrangement has succeeded so well, that notwithstanding the great number and duration of the experiments in which these burners have been tested, we have not yet been obliged to clean them. These large burners have not, as have those hitherto made with a single cylindrical wick, the disadvantage of

giving a reddish flame of little height. Their light is as white as it is brilliant; and the concentric flames mutually heating each other are lengthened with facility; it is even necessary to keep the chimneys up a little in order that the air, which is rapidly renewed, may be sufficient for the combustion of the disengaged gas, and, cooling the burner, prevent the too rapid distillation of the oil.

It might be feared that the rapidity of combustion would char the concentric wicks (especially when a four-wick burner is used) more rapidly than occurs with the ordinary single-wick burner, but experience has demonstrated the contrary; and we have, besides, found that wicks of the four-wick burner waste the less rapidly according to the effect they produce than the others, which is undoubtedly due to the great heat developed, facilitating the rise of oil in the wicks. We have kept the four-wick burner lighted for fourteen hours together without trimming, and the intensity of the light given by the lens which it illuminated was scarcely diminished one-sixth of its first intensity. Thus the four-wick burners may burn throughout the long nights of winter without requiring to be trimmed; it is sufficient to raise the wicks a little toward morning in order to preserve the flame at the height it was in the beginning.

The four-wick burner, 0.09 of a meter in diameter, burns nearly one and a half pounds of oil per hour when combustion is most active, and gives a light in proportion to the quantity of oil consumed; it is equal, as regards expense and the light produced, to seventeen Carcel burners. It is with this burner, placed in the center, that the illuminating apparatus composed of the eight large lenses, 0.76 of a meter square, is lighted. The lamp is fixed upon a table resting upon a cast-iron pedestal, which also supports the weight of the lenticular apparatus. This apparatus can easily be turned around its axis on the column by means of rollers, which move upon a circular projection on the top of the pedestal; it is put in motion by means of clock-work, which also regulates its velocity. In thus revolving around the central light, which is fixed, the lenticular apparatus throws out successively, upon all points of the horizon, the eight luminous cones from the lenses, separated by intervals of darkness; thus producing, to a distant observer, the appearance of a regular succession of flashes and eclipses. The angular extent of each flash, with a light of sufficient brilliancy to be seen at a distance of six leagues, being only $6\frac{1}{2}°$, while that of each interval of darkness is $38\frac{1}{2}°$, the duration of the flashes will be only one sixth that of the eclipses. This will be ample, however, as it is still less in most of our light-houses provided with flashing reflector lights. There are even some where the duration of the flashes is scarcely one-tenth that of the eclipses. Nevertheless it was desired that we should increase the relative duration of the flashes in the lenticular apparatus, as mariners generally find that the eclipses are too long.

It is easy to increase, to any desired extent, the divergence of the emergent rays by shortening or lengthening the distance of the lens from the central flame; but as the divergence in a vertical plane is increased in the same proportion as the horizontal divergence many of the rays would be lost, and the intensity of the light diminished in a much greater proportion, than the duration of the flashes would be increased. Thus, if by this means we double the duration of the flashes, their intensity is reduced to one-quarter of that which they had at first. In employing lenses with a shorter focal distance, the same disadvantage would occur, but the weight and cost of the apparatus would be diminished.

I propose to increase the duration of the flashes without diminishing their intensity and without increasing either the size of the illuminating body or the expenditure of oil. I accomplish this easily, without changing any of the general arrangements of the eight lenses, by utilizing the rays passing out above them, which would otherwise be lost. For this purpose I employ eight additional trapezoidal lenses of 0.50 of a meter focal distance, which are placed above the four-wick burner in the form of a truncated octagonal pyramid, like a dome or roof, through the upper opening of which the chimney of the lamp passes. These lenses embrace one-fourth of the surface of the sphere which has its center in the common focus of the large lenses, and therefore receive more than one-fourth of the total amount of

light emitted from the flame; since the upper hemisphere, as we have already observed, contains more light than the lower. But as we are obliged to employ silvered mirrors to reflect in a horizontal direction the luminous beams which pass through these lenses, a large part of the incident light will be absorbed notwithstanding their decided inclination, which is 25°; and I estimate that the incident light will be reduced one-half by its passage through the lenses and its reflection from the mirrors; hence the quantity of rays thus utilized is scarcely one-eighth of the total emitted from the flame of the four-wick burner. However, by so placing these additional lenses that a plane through their centers and the axis of the apparatus will make, with a corresponding plane through the centers of the large lenses, an angle of 7°, the duration of the flashes is at least doubled. It is necessary that the light from the small lens should precede that from the large one; for, if it followed it, the eye of the spectator would be fatigued by the brilliancy of the great flash, and would not see the other as distinctly.

The light transmitted from the small lenses is, without doubt, very inferior to that sent out by the large ones; first, because their area is only one-fifth of the latter, and second, because the rays are reduced in intensity by reflection on the mirrors. Nevertheless they are of sufficient intensity to be seen at a considerable distance. Observations made at a distance of 25 000 meters, on a moonlight night, show that the additional lenses double the duration of the flashes; and it is probable that they would be prolonged nearly as much at a greater distance. These small lenses, which, with their mirrors, only increase the price of the apparatus 2 700 francs and its weight only 128 kilogrammes, are therefore very useful, and even economical, since they collect and throw out, in a direction useful to mariners, a large portion of light that would otherwise be lost.

We can, strictly speaking, also direct toward the horizon the rays which pass out below the large lenses; but it would be difficult to do this without interfering very much with the service of the lamp, so I have decided to allow them to fall directly on the sea, where they will not be entirely useless, as with their plunging rays they light up the near vicinity of the light-house.

M. Arago, M. Mathieu and myself have compared in numerous experiments, the intensity of the light from lenses 0.76 of a meter square, with Lenoir reflectors having an opening of 31 inches, and with the double paraboloidal reflectors of Bordier-Marcet, 28 to 29 inches in diameter, the largest that have ever yet been employed for light-house illumination. We find that the lens illuminated by the four-wick burner gives, in the direction of its axis, a light three and one-fourth times as brilliant as that of the great Lenoir reflector, and four and a half times that of the double paraboloidal reflector of Bordier-Marcet. For the best revolving lights, we ordinarily use only two large reflectors,* pointing in the same direction, and the apparatus is composed of four such pairs set on the vertical faces of a rectangular prism; the flashes thus produced by the lenses are twice as brilliant in the axis as those of the Bordier-Marcet, or even the Lenoir reflectors, as it is almost impracticable to establish a sufficiently exact parallelism between the axes of the separate pairs of reflectors, so that the intensity of the two shall be double that given by either separately; this is especially true when such large reflectors as those of Lenoir are illuminated by small burners six lines in diameter. It is besides necessary, on account of the slight width of the luminous cones, to give to their axes a slight divergence in order to prolong the duration of the flashes, and consequently, the flashes produced by the large lenses must have twice the intensity of those of the best illuminated light-houses in France.

In order to compare the total amount of light in the flashes of the lenticular apparatus and reflectors, we measured the intensity of the light in many different directions, from the axis out to the extreme limits of the flash, by successively pivoting upon a revolving table

* In the light-house of Cordouan there are four great reflectors upon each of the three faces of the apparatus, which forms, instead of a square, a triangular prism; but it appears that a considerable divergence is given to their axes in order to prolong the duration of the flashes, for this light is no more brilliant than the others.

the lens and reflectors, and comparing the light to that of an ordinary lamp taken as unity by the method of shadows; then multiplying each partial intensity by the small corresponding angle described in the rotation, we obtained numbers showing their relative useful effects We thus found that the sum of the rays of the entire flash of each reflector was not one-third the sum of the rays in the flash of the lens provided with a four-wick burner. Thus, for the total effect, each lens of the new apparatus was equal to three great reflectors of Lenoir or Bordier-Marcet.

As to the quantities of oil consumed, we find that the apparatus composed of eight large lenses illuminated by a four-wick burner is almost as economical* as the large Lenoir reflectors with a small burner, and is twice as economical as the large reflectors of Bordier-Marcet, which have each two burners of ten lines diameter. Now we have not yet considered in our calculations the effect produced by the small additional lenses, which increase the duration of the flashes without increasing the expenditure of oil. We see, then, what very satisfactory results are obtained by lenticular apparatus; since, with the same consumption of oil, it gives an effect three times as powerful as that of an apparatus composed of eight large reflectors illuminated with the smallest burners; the weight and cost of the apparatus being only slightly increased. The weight is increased one-eighth and the price about three-fifths.

But another very important advantage, which will suffice to give the preference to lenses, even though their effect should not be superior to those of the reflectors, is the permanency of the glass and the durability of its polish. The cost of keeping the lenses in order will be almost nothing, and their cleaning will give much less trouble than reflectors, which must be frequently rubbed with red oxide of iron to keep up their polish. The lamp being at the center of a lenticular octagon, the inscribed circle of which has a radius of 0 93 of a meter, the lenses will not be as liable to become tarnished with oil as the reflectors are; it will therefore be ordinarily sufficient to dust them lightly with a feather duster, and they will rarely require wiping. When this is necessary, it will be well to sprinkle rouge on the linen cloth or chamois skin used for the purpose. In this manner they can be preserved almost indefinitely in the same condition as when they leave the shop of the optician, while silvered mirrors quickly lose part of their polish, and the cleaning of the eight large reflectors being a work occupying considerable time, it will often happen, through the negligence of the keepers, that they will not be as bright as they ought. Finally, it is necessary to re-silver them from time to time, when by friction the silver leaf on their interior surface wears off. The lenses require no such repairs.

As in a revolving lenticular apparatus the central light is fixed, it is as easy to illuminate it with gas as with oil If it be found economical or otherwise advantageous to do so, it will only be necessary to replace the lamp by a tube, surmounted by a burner arranged for concentric flames, and communicating at the lower extremity with the gasometer.† In fine, all the improvements that time and experience may develop in the production of light can be with the greatest facility applied to lenticular apparatus.

Having shown the principal advantages of this apparatus, I now propose to consider its disadvantages. The first that strikes us is the brittleness of glass; but I will call attention to the fact, that the pieces of glass that compose the lenses are sufficiently thick to prevent their being broken or detached except by a violent shock; and, with a little attention, it is

*There is still greater economy in the use of light if we substitute a three-wick for the four-wick burner, because the brilliant object is smaller relatively to its focal distance, and a less number of the rays is lost; but the intensity of the flash is also diminished, and especially its duration, and perhaps there would not be enough plunging rays. I think that a three-wick burner should only be used for light-houses of the second order, diminishing the focal length and the dimensions of the lenses.

†M. Arago and myself intend soon to try a burner of this kind, having six concentric flames, with gas produced by the distillation of coal. If we employ gas made from oil, which gives a more intense light, it is probable that four or five flames will suffice. The distillation of bad oils and other fatty matter being more simple than that of coal, appears preferable for light-house illumination; but before applying it, it will be well to ascertain why the English have not made use of it in their light-houses with fixed lights, and to be assured that it can be economically made in France. Finally, if we employ gas made in any manner, it will be necessary always to have in the lantern a spare lamp, to be used in case it should fail from any accident. The illumination by gas would have this advantage: during the longest nights the flames would be of a uniform height without requiring any care on the part of the keeper.

easy to avoid these accidents, which, besides, are easily repaired by means of fish-glue, unless the broken pieces are too small. In such a case it would be better to replace it by another lens and return the damaged one to the lenticular optician for repairs. But, as I have just said, such an accident would, with a little attention on the part of the keeper, rarely occur; and only because it is necessary to provide against all possible contingencies need an additional lens, like the one of the eight composing the apparatus, be kept on hand to replace one that might become damaged.

The fact that but a single lamp illuminates the apparatus might occasion some uneasiness; because if it should go out the light-house would be in total darkness, and vessels which an unfortunate chance might have led into the vicinity, might be cast upon a shoal that the light was intended to mark. But, while a violent puff of wind has sometimes extinguished all the lights of a reflector apparatus, it would not produce the same effect upon the flames of a four-wick burner, which by reason of their size and the activity of the combustion are much less sensitive to currents of air than those of an ordinary burner, as I have often had occasion to remark; for the same reason the wind which will put out a candle will not extinguish a torch. In truth, the four-wick burner might be extinguished by another cause—namely, the failure of the oil. But in order to weigh well this danger, which I have carefully considered, it is necessary to understand how the oil reaches the burner.

In order to render the service more easy and to keep the crown of the burner continually wet with a considerable overflow of oil, I have decided, after consultation with M. Rossel and several other members of the Commission of Lights, to apply to this lamp the ingenious idea of Carcel, and to make the oil rise in the burner by means of pumps driven by clock-work. In order to insure regularity and certainty of motion, this clock-work is moved by weights that descend through the interior of the cast iron pedestal which supports the lamp and service-table. Clock-work as simple as this and driven by weights is not liable to stop; but should this accident happen, or should the valves or plungers of the pump burst or get out of order, another lamp with a clock-work movement, but in which the motor is a spring, would be immediately lighted and substituted for the first. The mechanism of these lamps was devised and executed by M. Wagner, jr., with his usual skill.

As it might still be feared that the keeper might be asleep when the lamp got out of order, I have sought a means for awaking him when the oil stops flowing, and have found a very simple way of doing it; it consists in placing between the burner and the reservoir into which the overflow of oil falls a small tin cup attached to one extremity of a lever, and balancing, when full of oil, a counterpoise weight on the other. This little cup is pierced with a hole large enough to soon empty it when the overflow of oil stops, but not sufficiently large to discharge more oil than is received from the burners when the apparatus is working properly; so it always remains filled as long as the overflow is not diminished in quantity. But when the oil stops flowing, and before the light is extinguished, the cup empties, the counterpoise drops, and the motion of the lever disengages the spring of an alarm-bell. The noise of the bell continues for some time, and is sufficient to awaken the keeper.

It will not, perhaps, be useless to take still another precaution, by placing near the four-wick burner, and at the same height, the burner of an ordinary Carcel lamp which shall be kept lighted all night, so that, in case the former should fail in its supply of oil through any derangement of the pumps, and the keeper not be awakened soon enough to light the spare lamp before the other goes entirely out, the light-house will still be illuminated by the light from an ordinary Carcel lamp. The flashes thus produced would undoubtedly be much less brilliant and of shorter duration than those from the four-wick burner, but the light could be seen some distance, and would suffice to warn mariners who might at the moment be near the light-house. This Carcel lamp, which the keeper could take up at will and easily carry in one hand, would also be useful in going about the place at night and looking for such things as might be needed.

We think that with these precautions, the new system of illumination will be at least as reliable as that of the system now in use. In very cold nights there is less danger of the oil congealing than in an ordinary lamp, since the tepid oil which constantly overflows into the reservoir from the crown of the four-wick burner, and the proximity of the flame will always suffice to keep in a liquid state the oil in the reservoirs. The service of the four-wick burner is certainly somewhat more complicated than that of the ordinary one; but we are assured from a great number of experiments that but little attention is required to regulate the flames and keep them at the proper height. It is, besides, the only burner that the keeper has to attend; his attention is not divided, as with other apparatus, between eight, sixteen, or even twenty-four burners. There are no reflectors to polish, no burners covered with burned oil to be cleaned. It is only necessary during the day, to trim the wicks, renew the oil in the reservoir of the lamp, and draw the curtains around the apparatus to intercept the solar rays; the latter, without this precaution, might set fire to or melt anything placed at the focus of the lenses. The same precaution is taken when parabolic reflectors are used. The curtains will also serve, during the day at least, to keep out dust.

It is thus seen that the service will be very light. I am persuaded that the light-keepers at stations where the new apparatus are placed, will be more than satisfied by the simplification of their duties, and that, having no longer to divide their attention among a number of lamps, the light of the single lamp confided to their care will be improved

Should experience develop, in this lamp some defects which we have not remarked, it would be no reason for abandoning the lenticular apparatus, which presents so many advantages, for it will always be possible to perfect the mechanism of the lamp and obtain, at last, either with oil or gas. the central light necessary for the illumination of the apparatus.

Lenticular apparatus to show a fixed light can also be made, and it will be superior to the illuminating apparatus composed of parabolic reflectors; but, as fixed lights should illumine simultaneously the entire horizon, the same range cannot be had as in revolving or flashing lights, and as they might also be mistaken for others which, through accident or evil intention, might be shown on the coast, the Commission of Lights thought it better to employ only flashing or revolving lights, if their appearance could be sufficiently diversified. We have already partly succeeded in this by varying the periods of revolution of the different apparatus; but this cannot be done to any great extent, for the intervals between the flashes must be strikingly different in order that the sailor of the small coaster may not mistake them, and, besides, the velocity of rotation cannot be varied much without attendant disadvantages. The placing of panes of colored glass before the lenses or reflectors is another means of diversifying flashing lights, but the Commission of Lights doubted whether this plan was certain to give satisfactory results, and it has the disadvantage of occasioning a great loss of light For this reason I have sought to attain the same end, by so arranging an apparatus, that the intervals between its flashes shall be of unequal periods, according to the idea of M. Sganzin, Inspector General des Ponts et Chaussées. The first lenticular apparatus made by M. Soleil was on this plan; two of the eight large lenses being each replaced by two of half width, embracing an angle of 45° in a vertical, but only 22½° in a horizontal direction, and set on opposite sides of the apparatus. The result of this arrangement is, that the angular intervals between the middle of the successive flashes, and consequently the corresponding intervals of time, form the periodic series 1, 1, ¾, ½, ¾; 1, 1, ¾, ½, ¾, &c.* There is also a great

*A more simple series could be had by a combination of eight half-size lenses and four large ones, in which each of the latter would be followed by two of the former, which would give for the intervals of time between the middle or the ends of the successive flashes the periodic series 1, 1, ⅔; 1, 1, ⅔, &c.; then mariners would not be compelled to observe so great a number of flashes in order to recognize the law of the period.

But there is another combination, which M. de Rossel and myself have thought would give to a flashing light a character still more easy to recognize: it consists in revolving around the central light sixteen half-size lenses, each embracing an angle of 45° in a vertical and 22½° in a horizontal direction, while the truncated pyramid of small lenses, which forms a kind of roof over the lamp, would still be composed of eight lenses, the flashes of which would precede by 7° those of the eight corresponding half-size lenses with which they would be connected. Thus, upon two consecutive flashes, the first, composed of that from the additional lens and that of the half-lens, would be at least twice as long as the one that followed it, produced by a half-lens only, from which would result a succession of flashes alternately long and short. The system would possess still another advantage, the sum of the durations

difference in the intensity of the flashes, since six of them are almost twice as bright as the other four. But the light of the weaker being still very intense, and this distinction only being recognized from memory, it appears from our experiments, that a light-house could not be distinguished by it in cases where the intensity of the lights was weakened by mist or fog, or by the great distance of the observer; because, at six leagues distance, and in the moonlight, some attention is necessary to note the difference in the intensity of their flashes, though those of the half-lenses are still bright.

Large lenses have been employed with success by MM. Arago and Mathieu as signals in geodetic surveys, which were made toward the end of last autumn upon the coasts of France and England. One of these lenses, illuminated by a four-wick burner and placed at a distance of fifty English miles from the observer, was easily seen with a telescope an hour before sunset, and with the naked eye an hour after. It then appeared as bright as the fixed light of an English light-house off in nearly the same direction, and only fifteen miles away—that is to say, about one-third the distance. This example suffices to give an idea of the range and power of the large lens apparatus.

Not only will they be useful for the illumination of light-houses, but they will doubtless be of use in the advancement of science. They furnish a powerful instrument, by which we can submit to the most intense heat, in the interior of a glass shell, bodies that we may wish to melt or volatilize, keeping them from the air or putting them in contact with another gas; many experiments, which could neither be made with the ordinary nor with Neuman's blow-pipe, will easily be made in this manner. May we not, at some future time, owe to these burning-glasses discoveries as surprising as those with which the voltaic pile has enriched chemistry?

If they render important service to scientists, and above all to mariners, we will be indebted to the enlightened zeal with which M Becquey always welcomes useful inventions and hastens the perfecting of them. The encouragement that he gave to M Soleil, was not confined to ordering the apparatus; the establishment of the necessary machinery for their manufacture required the advancement of considerable funds. M. the General des Ponts et Chaussées came to the assistance of the manufacturer, and by paying a certain amount in advance, encouraged him in the new undertaking, to which he devoted all his energies, assuring its success from the outset.

I ought to add that the zeal with which M. de Rossel supported the proposal for introducing the new system of light-house illumination, as soon as he saw the effect of our first lens, as well as the advice and encouragement that he gave us while the work was in progress, has contributed in a large measure to hasten the completion of the lenticular apparatus now finished.

The first one, the lenses of which were made of small pieces, and the outer surfaces segments of spheres, was tried last year before M. the Director General des Ponts et Chaussées and the members of the Commission of Lights, who were very well satisfied with the intensity of the light.

The second one, composed of eight large and eight small lenses, is to be submitted to a series of similar but more complete experiments, in which will be employed the mechanical lamp with clock-work movement designed to illuminate the light-house of Cordouan.

of the flashes would be nearly equal to that of the eclipses. The half-lenses would have less range than the entire ones, which embrace an angle of 45° both horizontally and vertically; but the intensity of the light would scarcely be reduced one-half, because the parts that are suppressed to the right and left of the axis in the full lens, in order to form the half-lens, will furnish less light than those that are left, which are nearer the axis; these half-lenses would give a light at least as brilliant as that of two thirty-inch parabolic reflectors. Thus, in sacrificing in this way a part of the intensity of the flashes to their duration, it is done in an economical manner, since in the total, a little light would be gained.

Instead of adding the flash of each additional lens to that of a half-lens, it could be inserted between the flashes of two consecutive half-lenses; it would then be distinguished by a difference of intensity which would be sufficiently pronounced to strike the eye, and there would be, besides, a great difference between the intervals of time that separate the centers of successive flashes, since there would result from this arrangement the very simple series 1, ½, ½; 1, ½, ½, &c. The particular effect of this flashing-light would be to show very brilliant flashes succeeding each other at equal intervals, but between which, and in pairs only, will be inserted flashes much less brilliant.

From a preliminary experiment made at Montmélian, situated 16 400 toises* from the Arc de Triomphe of the Barrier de l'Etoile, upon which an apparatus was placed, it appears that the duration of the light (under favorable conditions) is one-half the duration of the eclipses; that a sensible diminution of the light, which occurs at the junction of the flash of the large lens with that of the small one, (but without absolute eclipse,) is perceived during one-fifth the total time of its visibility; and finally, that both flashes, especially the one from the large lens, are very fine at that distance.

*Postscript.*

Since reading this memoir, I have thought of a means of prolonging the duration of the flashes, without changing the arrangement of the large and small lenses, by the addition of an apparatus which will not interfere with the service of the lamp, and will leave the table on which it rests entirely free. It consists of a system of small silvered mirrors, fixed below the large lenses and between the uprights which sustain them, and arranged like the slats of a Venetian blind; instead, however, of being parallel, each set should have the proper inclination, to reflect the rays parallel to each other, and each bunch of rays corresponding to a large lens should make an angle of 14 or 15 degrees with the axis of that lens, placed in advance of the direction of motion, so that the flashes produced by this system of small mirrors will precede the flashes of the additional lenses by the same angular distance that the latter precede the flashes of the large lenses. I think we can thus succeed at small expense, and without adding more than 200 pounds to the weight of the apparatus, in giving to the flashes a duration nearly equal to that of the eclipses. Finally, I propose to soon make a trial of this addition to the apparatus, and to verify by experiment these approximate theoretical results.

*A toise is equal to 6.56 feet.

VII.

# INSTRUCTIONS

FOR THE

# MANAGEMENT OF LIGHT-HOUSES HAVING LENTICULAR APPARATUS*

OF

# THE FIRST THREE ORDERS.

## FIRST SECTION.

### ARRANGEMENT OF THE ILLUMINATING APPARATUS AND LAMPS.

### CHAPTER I.

#### GENERAL DESCRIPTION.

Three orders of illuminating apparatus.

1. The lenticular apparatus employed for the illumination of the larger light-houses, are divided into three orders, according to their sizes and the calibers of their lamps.†

Optical part and frame.

2. The optical part of this apparatus is composed of LENTICULAR PANELS and CATADIOPTRIC PANELS or MIRRORS. These pieces are held together by a frame called the *Armature*, which is supported by a hollow cast-iron column.

| | Meters. |
|---|---|
| The interior diameter of an apparatus of the first order is - | 1.84 |
| That of an apparatus of the second order - - - - | 1.40 |
| That of an apparatus of the third order, large model - - | 1.00 |
| That of an apparatus of the third order, small model - - | .50 |

Lamps.

3. Each lenticular apparatus is illuminated by a *lamp* the burner of which is placed at the common *focus* of the pieces of the optical part.

Three kinds of lamps.

4. Three kinds of lamps are in use:

1st. Mechanical lamps.
2d. Moderator lamps.
3d. Constant-level lamps.

In the first, which may be designated as *mechanical pump-lamps*, the oil is forced up into the burner by pumps driven by clock-work machinery. The motive power of this machinery is a weight, the connecting cords of which descend through the column supporting the apparatus.

* These instructions are, for the most part, the same as those drawn up by M. L. Fresnel in 1835, and by M. L. Reynaud in 1860. Various changes made from time to time, particularly the introduction of mineral oil for light-house illumination, have made some additions and changes necessary.

† Small catadioptric apparatus lighted by single-wick lamps constitute a fourth order; but here we are considering only light-houses proper, instructions for the management of the smaller lights being given separately elsewhere. (Document No. VIII.)

*Moderator lamps* are distinguished from the preceding by the absence of the clock-work. The ascent of the oil in the burner is effected by the pressure of a piston which descends into the cylinder forming the body of the lamp. This piston is itself moved by weights placed upon it. Sometimes, in two-wick lamps, it is moved by a spiral spring.

*Constant-level lamps* have generally a cistern which sets into the reservoir or body of the lamp; this cistern has at its lower extremity a lift-valve, which is raised the moment the cistern is put in place, and communication with the burner is thus opened.

Mechanical lamps.

5. Two kinds of mechanical lamps are now in use—the clock-work lamps, which are most used, and the lamps with a pin-escapement, called the *Henry Lepante*, which are still found in some light-houses.

Oil-cistern.

6. In both kinds the reservoir or lamp-body is a cylindrical copper vessel.

This vessel occupies the middle part of the frame and holds about double the quantity of oil necessary for fifteen or sixteen hours burning.

Clock-work.

7. The *clock-work* is placed under the cistern, and is differently made, according to the kind of lamp, as follows:

Clock-work lamps.

1st. *Clock-work lamps*.—A reciprocating rotary motion is transmitted to two vertical rock-shafts by means of cranks and cog-wheels. These shafts pass through the oil-cistern, and by means of two levers attached to their upper extremities work the feed-pumps. A fly with fans regulates the motion.

In the *Wagner lamps* the flow of oil to the burner may be regulated by turning a screw placed in the upper part of the pump-case.

In the old clock-work lamps the motion is transmitted by bevel-wheels to a single vertical shaft, which works the feed-pumps by means of little cog-wheels.

Escapement lamps.

2d. *Escapement* or *Henry Lepante lamps*.—The mechanism in this case consists of a drum carrying a crown-wheel, on both faces of which are pins provided with friction rollers, which form the escapement with four points of bent levers. These levers communicate by connecting rods with two shafts which traverse the oil-cistern, and by means of two fixed levers at their upper extremities put the feed-pumps in motion.

The mechanism has for a regulator a small aperture, made in a diaphragm, placed in the upper part of the pump-case.

In some pumps of this kind there is added to the pump-case a small pointed screw, which penetrates this aperture, and by means of it the flow of oil may be decreased if necessary.

Pump-case.

8. The *pump-case* is that part of a mechanical lamp which contains the feed-pumps.

It communicates with the oil-cistern by a suction-tube, having at its lower end a small strainer. The pistons have calf-skin plungers, and the valves, washers of the same leather.

Moderator lamps.

9 *Moderator lamps* are of two kinds—those with *weights* and those with a *spring*.

The cistern which reaches to the base of the lamp is twice the height and has twice the capacity of the mechanical lamps.

Moderator lamp with a weight.

1st. *Moderator lamps with weights*.—A cast-iron piston, bound with leather, and of such a size as to gently slide in the lamp-cistern, is connected above to a horizontal shaft by a chain which is fastened at the other end to the middle of the piston, and winds on a pulley occupying the middle of the shaft.

On the piston are placed the cast-iron or leaden weights used to make it descend when wound up.

By turning the shaft with a winding key the chain is rolled around the pulley and the piston ascends; then, left alone, it causes by its pressure on the oil a flow to the burner.

The regulator is a small orifice, into which a needle of conical form is pushed or withdrawn, to diminish or increase the supply.

This device is usually so arranged as to be self-acting, and the increase of force necessary to cause the oil to rise as the level is lowered is provided for, as follows:

The winding shaft has on it a flat screw-thread, which engages a female screw cut in a piece which slides in a groove parallel to the shaft. This piece, therefore, moves in a direction parallel to the axis of the shaft when the latter turns.

The head of the conical needle traverses this piece, and as the piston descends, unwinding the chain, the axis turns and the piston and needle move so as to open the supply orifice more and more.

In some lamps the movement of the needle is independent of the shaft, and is effected by hand alone. The keeper can then more conveniently regulate the supply of oil, according as it is in a more or less limpid state.

By a cock at the upper end of the supply-tube the flow can also be regulated, or stopped altogether if required.

Moderator lamps with a spring.

2d. *Moderator lamps with a spring.*—The lower end of a spiral spring is attached to the piston placed in the body of the lamp or reservoir. This piston, a sheet-iron disk with a leather washer, rests on the oil and forces it up a tube which, passing through the cistern, reaches the burner. The ascent of the oil is regulated by an iron stem fixed to the burner and entering the tube for a certain distance, which distance is decreased as the piston descends and the tension of the spring diminishes.

Constant-level lamp.

10. In *constant-level lamps* the cistern usually has in its lower part a lift-valve, which opens when its stem strikes the bottom of the lamp.

11. If the lamp be intended for burning mineral oil, the upper part of the cistern rests on a rack so that it can be raised or lowered at will, and thus a variation of the level of the oil in the burner be effected.

Some constant level lamps for mineral oil have a large cistern hermetically closed, and a small one open to the air. The upper part of the large cistern is made with a funnel to facilitate filling; when the oil is poured in the supply tube is closed by a cock. The lower part of the supply tube dips into the little open cistern in which the level of the oil is adjusted. The lower part of the tube can be slipped up and down, thus raising or lowering the level of the oil.

Burners.

12. *Lamp-burners* are provided with from two to five *concentric wicks*, according to the order of the light and the intensity required.

The lower end of each wick is fixed by a ring or thread to a circular carrier, and raised or lowered by means of a small rack.

A pipe forming the stem of the burner supplies the wick with oil. This is usually fitted to the upper part of the lamp by a screw-joint provided with a leather washer.

13. In mineral-oil lamps the pipe forming the stem of the burner has a little tube or constant-level cistern, which keeps the oil always at the same height in the burner, and also restores the overflow to the lamp-cistern.

In constant-level lamps proper, the pipe connecting the cistern and the burner has a cock for stopping the flow of oil to the burner.

The mineral-oil burner is provided with a small metallic disk, resting on a stem in the axis of the burner, by which it can be slightly raised or lowered. The proper height for it is determined by circumstances, especially by the temperature; it is found in each case by trial.

Burners with more than two wicks have an exterior movable gallery which can be raised or lowered. By properly adjusting it and the central disk at the same time, the currents of air which give the best flame can be produced.

Glass chimney and damper.

14. The *glass chimney* is supported on a cylindrical holder, which can be raised or lowered by turning it to the left or right.

The chimney is continued by a sheet-iron or copper pipe, inside of which is a *register* or *damper*, by means of which the opening of the pipe can be altered at will. In some light-houses where the chimneys are very short this piece is held by an iron collar fixed to the apparatus; in others it simply rests on the chimney, sliding over the end.

Consumption of oil.

15. The consumption of colza oil per hour in a mechanical lamp in full operation is as follows:

| | Grammes. |
|---|---|
| In a four-wick lamp | 760 |
| In a three-wick lamp | 500 |
| In a two-wick lamp | 175 |

The consumption of mineral oil is somewhat less for the same number of wicks; for a five-wick burner it is about 840 grammes.

Ascent of oil.

16. To fully develop the flame, and at the same time sufficiently cool the crown of the burner, the clock-work must raise at least four times as much colza oil per hour as the lamp will consume; that is—

| | Grammes. |
|---|---|
| For a four-wick lamp | 3 040 |
| For a three-wick lamp | 2 000 |
| For a two-wick lamp | 700 |

The excess of oil overflows the burner and falls back into the cistern.

17. In mechanical and moderator lamps for mineral oil the oil does not reach the crown of the burner: the excess should therefore be less; it is sufficient if the oil overflows drop by drop through the drip-tube.

In the constant-level lamps there is no overflow.

Level of oil in the ourner.

18. The level of mineral oil below the crown of the burner should vary according to circumstances, principally according to the temperature. The distance from the oil to the crown should be a little more in summer than in winter. It varies from 40 to 50 millimeters ($1\frac{1}{2}$ to 2 inches) in lamps with four or five wicks, and from 25 to 35 millimeters (1 to $1\frac{2}{5}$ inches) in lamps with two or three wicks.

Motor weight of mechanical lamps.

19. The motor weight in mechanical lamps should be suspended from the hook of the movable pulley of a set of falls.

When the mechanism of these lamps has been well made and is properly cared for, the weight (acting through a set of blocks and falls) necessary to keep it regularly running does not exceed—

| | Kilogrammes. |
|---|---|
| In four-wick lamps with colza oil | 35 |
| In those with three wicks | 30 |
| In those with two wicks | 20 |

In mechanical lamps with mineral oil the weight should be less, as there is less oil to be raised. The weight is from 15 to 20 kilogrammes in five-wick lamps, and less in the others.

Revolving machinery of flashing-light apparatus.

20. In light-houses with variable lights the revolving part of the illuminating apparatus is put in motion by clock-work, which has for a regulator a simple fly-wheel or governor.

## CHAPTER II.

### OIL USED IN LIGHT-HOUSES.

Oil used in light-houses.

21. The oils used in light-houses are *colza oil* and *mineral oil.*

Colza oil.

22. The colza oil should be of the best quality, perfectly pure, and clarified.

The oils delivered by the contractor are first tested by drawing a certain quantity from each cask, and burning it in two or three night-lamps.

The oil will be refused if the lamps, properly arranged, go out of themselves before burning twelve hours.

If they do not burn twenty hours the oil will be considered, if not bad, at least of doubtful quality. In this case, or any other where there is doubt, the decisive test is to compare the oil with colza known to be of the first quality. The oil to be tested will not be considered proper for light-house illumination if, during combustion of sixteen hours, it does not give as good a flame as the standard oil; or if it deposits more carbon on the wicks, though equal in other respects, it should not be received for use in light-houses.

In this comparative test, either ordinary constant-level lamps with double-current-of-air or the regular light-house lamps will be used.

The quality of the oil can also be tested by the areometer.

Mineral oil.

23. The mineral oil must be of the best possible quality and perfectly purified.

It must fulfill the conditions of the contract with regard to specific gravity and inflammability.

To test the specific gravity a test-glass is filled with the oil, the areometer plunged in, and the specific gravity is indicated by the division of the scale on a line with the surface of the oil. The standard required is from 0.810 to 0.820 at a temperature of 15° centigrade, (59° Fahrenheit.)

This temperature is obtained in winter by heating the oil in a water-bath, and in summer by plunging the test-glass containing it into cool water. If these methods are not available, the specific gravity and temperature of the oil are taken, and a correction of 0.00074 is added for every degree below 15° centigrade, or deducted for every degree above.

To test the flashing point a special apparatus provided for the purpose is used.

The oil to be tested is poured into a little copper capsule, placed in a water-bath, heated by a spirit-lamp; a thermometer, so suspended as to dip into the oil, gives the temperature. When the thermometer shows a greater degree of heat than that mentioned in the contract, the light of the spirit-lamp is extinguished, and as the mercury slowly descends a lighted match is applied to the surface of the oil; if ignition takes place, the degree marked by the thermometer should not be lower than that mentioned in the contract.

Precautions to be taken in the use of mineral oil.

24. The mineral oil used in the Light-house Service is not as liable to explode as are most of the oils or mineral extracts offered for sale, and it can be employed with safety when the foregoing conditions are observed.

Still the following precautions should be observed:

The cans used for storing it should be tightly closed and kept in cool and well-ventilated places.

The oil should be drawn only by daylight. It is important that the vessels should not be entirely filled; sufficient space should be left above the surface of the oil for its free expansion.

No smoking should be allowed in the oil-room, nor should an uncovered light be taken there.

In case of fire, sand, earth, or ashes are better than water for extinguishing burning mineral oil.

The oil-room should, if possible, be on the ground-floor or in a cellar; it should be paved with stone laid in lime or cement-mortar.

The doors communicating with other parts of the house and with the exterior should have stone sills rising above the paved floor, so as to retain any liquid which may be spilled.

The oil-room should be separated from other rooms by solid walls of masonry. It should be well lighted by day and perfectly ventilated. It should be easy of access, and not in communication with any room where wood or other combustible material is stored.

## CHAPTER III.

### SETTING UP LENTICULAR APPARATUS AND LAMPS.

Adjustment of the lenticular and catadioptric panels.

25. The *lenticular panels* and *catadioptric panels* of apparatus are solidly fixed in their frames by screws and bolts, and cannot be displaced, except by quite unusual accidents, which it seems unnecessary to consider here.

Adjustment of mirrors.

26. As to the mirrors arranged in horizontal courses on circular frames, they are not mounted with the same stability as the lenses, and they might become displaced, either by a slight jar or by ordinary rubbing, if they be not firmly held while cleaning them.

It can be seen that one of these mirrors is out of place, if, in looking through the focus of the apparatus, the horizon is not seen reflected from the center of the glass. To restore it to its former position it is sufficient to shift the nuts on the three copper clamps which hold it in its frame.

This operation, which requires two persons, should in no case be undertaken, except on consultation with the engineer or assistant engineer charged with the supervision of the light.

Setting up the service-lamp.

27. The *service-lamp* of a lenticular apparatus is usually placed on a tripod having three vertical rods cut with screw-threads, and provided with leveling-nuts. The foot of the lamp slips over these rods and there is sufficient play to correct the centering when necessary.

When properly set up the lamp will be placed as follows:

1st. The middle of the burner will be exactly in a vertical line drawn through the *focus* of the apparatus.

2d. The crown of the burner will be placed below the common foci of the lenses, at a distance marked on a gauge made for the purpose.

3d. The upper part of the crown will be perfectly level.

28. The various operations necessary to satisfy these three conditions are usually effected in the following order:

1st. The center of the apparatus is determined by stretching two threads between the middle points of four uprights of the lens-frame, so they will be at or nearly at right angles to each other.

2d. On the burner is placed the gauge mentioned above; the center is then plainly indicated.

3d. By the leveling-nuts of the tripod the lamp is brought to about its proper height, then a small spirit-level is placed on the burner, and by it the lamp is leveled so that the upper part of the burner is horizontal.

4th. To *center* the burner, that is, to make the middle of the gauge correspond with the point where the two threads cross, the upper nuts of the leveling-screws are lowered and the lamp is moved horizontally to the proper position.

5th. The small level is replaced upon the burner, and if it be found that it is not now horizontal another adjustment is made, care being taken to satisfy at the same time the first two conditions relative to the centering and the height.

6th. Usually the burners of constant-level lamps cannot be moved horizontally; it is adjusted at the proper height by means of washers placed under its joint.

Height of the centering-gauge.

29. The height of the gauge which determines the vertical distance of the burner below the foci of the lenses should vary according to the elevation of the focal plane above the level of the sea. This height is shown in the following table:

| ELEVATION OF THE LIGHT ABOVE THE SEA. | HEIGHT OF THE GAUGE FOR A LIGHT OF THE— | | |
|---|---|---|---|
| | 1st order. | 2d order. | 3d order. |
| | *Millimeters.* | *Millimeters.* | *Millimeters.* |
| 30 meters and less | 28 | 26 | 24 |
| From 31 to 60 meters | 27 | 25 | 23 |
| From 61 to 90 meters | 26 | 24 | 23 |
| From 91 to 120 meters | 25 | 23 | 22 |
| From 121 to 180 meters | 24 | 23 | 22 |
| Above that | 23 | 22 | 21 |

30. It is also easy to practically verify the height of the burner by using, whatever may be the elevation of the light, an ordinary gauge of 28 millimeters for the first order, 26 for the second order, and 24 for the third order. It is sufficient to place the eye at the level of the gauge and a short distance from it, so that the gauge may be between the eye and the center of one of the lenses. There is then seen in the lens an inverted image of the sea-horizon, and the top of the gauge should exactly touch the horizon line.

31. In mineral-oil lamps, the disk of the burner should be nearly on a level with the center of the lenses for two-wick burners; it should be 4 or 5 millimeters below for three-wick burners, and 6 or 8 for those with four and five wicks.

Spare lamps.

32. Spare lamps should always be in readiness to replace the service-lamps in case of necessity.

## CHAPTER IV.

### MANAGEMENT OF THE LAMPS.

Management of the lamps.

33. To prepare a lamp for lighting, it is necessary to conform to the following directions:

Placing and trimming the wicks.

34. For lamps burning colza oil, the first thing is to fit the burner with its wicks, proceeding for each as follows:

The *wick-carrier*, being detached from the burner, is placed on the mandrel made to receive it; the wick is drawn over the mandrel as far as the catch of the wick-carrier, upon which it is tightly fastened by a ring; the lower edge is then carefully trimmed and covered with the ring, so as not to obstruct the ascent of the oil

If the diameter of the wicks be a little too large, it should be reduced by carefully removing some threads of the warp.

The wicks being placed, they are lowered, then with sharp curved scissors trimmed even with the burner.

If points or threads are left sticking up above the crown of the burner, their irregularities will cause the flame to smoke, and they will soon be covered with little deposits of carbon called *thieves*. It is, therefore, very essential that the wicks should be cut evenly, not only in this operation but in the successive trimmings

Still, if the keepers observe that, from some special fault of the burner, or because of the pipes or pieces which cross the air-tubes to unite the various cylinders of the burner, there are always points formed in the flame at certain parts of the circumference, they should, when cutting or trimming, slightly cut away the wicks in those places so as to prevent the forming of the points

Experience and trial are the only guides in such cases.

35. For lamps burning mineral oil, the disk at the center of the burner is first removed. The wicks are carefully fastened to the wick-carriers by coarse thread, and are then examined to see that they can be freely moved up and down without forming any bunches, which would obstruct the ascent of the oil.

The wicks are lowered to saturate them with oil, carefully cut, and then, in order to prevent any chance of ragged edges, lighted for a few moments, observing the precautions mentioned in Article 38, and then wiped

Filling the cistern.

36. Having fitted the burner, the oil is poured into the cistern, and the clock-work or piston wound up with the key. After a few moments, the oil forced up by the pump, or (in moderator lamps) simply forced up by the piston, fills the wicks and overflows by the drip-tube.

In *moderator lamps* especial care should be taken, when winding up the piston, to close the cock placed at the upper part of the supply-tube, and to open it as soon as the piston is wound up.

It is necessary to entirely fill the cistern of these lamps before lighting; in mechanical lamps it is sufficient to put in double the quantity required for the night's use.

In *constant level lamps* the cistern contains sufficient oil for the longest nights. At the moment of lighting it is only necessary to open the cock which establishes communication between the cistern and the burner.

Testing the overflow.

37. To ascertain if a mechanical lamp pumps up sufficient colza oil, there may be placed under the drip-tube a vessel holding 250 grammes, and the time it takes to fill it noted. The conditions being as above, this time should be, before lighting, about 5 minutes for a four-wick lamp, about 7 minutes for a three-wick lamp, and about 21 minutes for a two-wick lamp.

For mineral oil it is sufficient if it drips from the overflow-tube drop by drop.

Lighting a four-wick burner.

38. When the wicks are sufficiently saturated with oil the lamps may be lighted, the following precautions being observed:

For colza-oil lamps, first raise the central wick (No. 1) about 15 millimeters, and by aid of a lucerne or lighting-lamp ignite it at two opposite points; then lower it as soon as it is possible to do so without extinguishing it. Proceed in the same way with wicks Nos. 2, 3 and 4, lowering them successively as soon as they are ignited, so as not to smoke the apparatus. This done, put on the glass chimney and place the smoke-funnel upon it.

For mineral-oil lamps, raise the wicks from 1 to 2 millimeters above the burner, and set the little metallic disk somewhat above its usual position. Light each of the wicks, and immediately lower them a short distance below the crown of the burner, after which put in place the chimney and the smoke-funnel.

If the burner be provided with a movable gallery outside the wicks, its height must be properly adjusted in order to obtain a regular and well-developed flame.

It is essential that there should be very little flame at the commencement of the lighting, for in a few minutes the burner becomes heated, the oil flows more freely to the wicks, and the flame rapidly rises.

Position of the damper and the chimney-shoulder.

39 For a few moments after lighting the damper should be inclined 45°, and the shoulder of the chimney held as high as possible, so as to prevent the breaking of the glass, which would result from too rapid heating; afterward the chimney should be gradually lowered to the point which will permit the development of the flame prescribed in Article 43 while maintaining its full brilliancy. If too low, it will prevent the flame from attaining the desired height; if too high, it will produce a red and dull flame.

The irregularities which appear at certain parts of the flame can sometimes be made to disappear by simply turning the chimney in its holder As it is never centered with perfect exactness on the burner, it may be that the slight irregularities it presents will neutralize the irregularities in the flame.

Management of the lamp during the first hour.

40. During the first hour after lighting, the height of the wick above the burner should not, for colza-oil lamps, exceed 5 to 6 millimeters, and care should be taken that the flames do not mount too rapidly, as this might break the chimney and char the wick.

41. Mineral-oil lamps should give but little light during the first moments of lighting. After half an hour the wicks should be raised a little above the crown of the burner, the chimney and the little disk gradually lowered, and the damper opened more or less, so as to obtain a regular, white, and well-developed flame.

To obtain a good flame it is generally necessary, in practice, to keep the central wicks about 1 millimeter below the exterior ones.

Use of the damper to regulate the flames.

42. As the combustion becomes more active the damper is opened as much as is necessary, and the wicks raised 7 millimeters above the burner for colza-oil lamps, and 3 to 4 millimeters for mineral-oil lamps. It is very rarely necessary to exceed these heights. When the damper is opened the flame becomes shorter and white; when it is closed it lengthens, becomes reddish, and smokes.

Mean height of fully developed flames.

43. At the end of an hour the flames thus managed will be fully developed, and their height, with colza oil, will be as follows:

For a four-wick lamp, 10 to 11 centimeters.
For a three-wick lamp, 8 to 9 centimeters.
For a two-wick lamp, 7 to 8 centimeters.
The flames of mineral-oil lamps attain about the same heights.
The flames are kept at the desired heights by properly adjusting the damper.

Alarm-bell.

44. An alarm-bell is attached to the service-lamp of lenticular apparatus to warn the keepers. The escapement of this alarm is held by a lever which carries at its other extremity a cup pierced with a little hole. This vessel is placed under the drip-orifice of the burner and when full of oil keeps its counterpoise; but if the ascent of oil ceases the cup empties, the counterpoise falls and raises the catch of the alarm, which then sounds.

# SECOND SECTION.

## MANAGEMENT OF THE LIGHT.

---

## CHAPTER I.

### DUTIES OF THE EVENING AND NIGHT.

45. The night duties in light-houses having lenticular apparatus are performed by two or three keepers, who have alternate watches. **Night duties.**

46. Each evening, three-quarters of an hour before sunset, the two keepers on duty for the night will go up to the lantern after providing themselves with a *lighting-lantern*. **Evening duties.**

47. If the day-service has been regularly performed, the following state of things should appear : **Preparations made during the day.**

1st. The lamp of the apparatus ready for lighting will be found with its cover on.

2d. The motor weight, entirely wound up, will be held at the height of the service-table by an iron pin.

3d. The chimney, laid in a little box, should be found placed on that table, as should also its smoke-funnel, (if not attached to the apparatus,) and the service-box fitted with the utensils ordinarily used in lighting.

4th. Four glass chimneys, and a spare burner fitted with *dry wicks*, should be found kept in reserve in one of the divisions of the staging of the service-table, if the apparatus be of the first order, or in the little closet of the lantern-room, if it be of a lower order.

5th. The two spare lamps, fitted with their covers and cords, (if they are clock-work lamps,) should be in one of the closets of the watch-room; one of them, which in case of accident is to be placed in the apparatus, should be fitted with the extra pulley of the motor-weight.

6th. An oil-bucket filled with oil strained the previous day should be ready in the watch-room.

This does not apply to mineral oil, which does not need straining, and should not be brought up until the moment it is required for use.

7th. If there be mechanism for revolving the apparatus, its motor weight should be found entirely wound up, the main wheel held by its clutch, and the bevel-wheels out of gear.

In the new machines for revolving the apparatus the wheel for communicating the motion remains constantly in gear; it is set going, when necessary, by a simple disengaging coupling. This observation applies also to Articles 49 and 61.

8th. A night-lamp should be kept in the watch-room, so that a light may be had in the light-house; and a lantern ready to be lighted should be placed near it, so that it may be used in case it becomes necessary to trim or change the service-lamp.

9th. The lantern curtains should be down, and the optical parts of the apparatus covered with the covers intended to protect them from the rays of the sun.

48. Lighting will be commenced at sunset, so that by nightfall the light may be at its full brilliancy. **Lighting of the lamps of the apparatus.**

For this operation and for the management of the lamp, the instructions already given will be followed.

A quarter of an hour after sunset, the covers will be taken off, the curtains raised, and the glass of the lantern carefully wiped within and without.

Setting in motion the clock-work.

49. If it be a variable light, the clock-work will be set going immediately after lighting. To do this, lower the pivot of the driving-wheel, so that the bevel-wheels gear properly together, and then draw back the clutch of the main wheel.

Trimming the lamps.

50. If, after burning some hours, the wicks are found to be so much charred that the flame cannot be kept at a proper height by half closing the damper, or by raising the wicks 2 or 3 millimeters, it will then be necessary to trim them.

This operation, which under such circumstances requires two keepers, should be performed in the following manner:

1st. In the interior of the apparatus hangs the lantern, which has been prepared for the purpose in the watch-room, and on the stage of the apparatus or the service-gallery place the lighting-lantern and two spare chimneys perfectly dry and well polished.

2d. Extinguish the light of the apparatus by lowering the wicks, then take off the smoke-funnel if it be not a fixture, and remove the chimney, using a perfectly dry cloth, which will enable one to take hold of it without burning the hands; then roll the cloth about it, place it in the box and leave it to cool gradually, so that it may not break.

3d. Stop the flow of oil either by turning the cock, or by winding up the motor-weight and suspending it at the height of the service-table by the iron pin provided for the purpose; then trim the wicks as quickly as possible, after which set the oil again flowing and re-light the wicks, raising them at once to a height of 7 millimeters for colza-oil lamps, and 3 to 4 millimeters for mineral-oil lamps. This done, put the still hot chimney in place, and the flames resume their former height in a few moments.

51. The trimming of the wicks may also become necessary when "thieves" form and cause the flames to redden and smoke.

These carbonaceous deposits are ordinarily caused either by jags or threads left on the edge of the wicks, or by refuse matter which may be attached to them or which may obstruct some of the conduits for the circulation of air.

It may also happen that the formation of these deposits results entirely from the inferior quality of the oil.

52. In the case of mineral-oil lamps, if it becomes necessary to trim the wicks during the night, it should be done as follows: the ascent of the oil to the burner is stopped, the wicks lowered, the smoke-funnel raised and the chimney taken off, the flame is blown out, and the metallic disk removed by means of flat pincers; it is then ready for trimming.

For this purpose, the wicks are raised to such a height, that the lower part of the charred portion just touches the edge of the burner, then with a little brush the top of the charred wick is removed, and, if necessary, any jagged portions or threads cut away with curved scissors. A bottle-brush is then passed through the interior air-tubes of the burner, to remove any fragments of wick that may have fallen into them. The disk is replaced, the oil again set flowing and the wicks re-lighted, observing the precautions before mentioned.

It often happens that after burning about six hours there is formed on the wicks a small hard crust which arrests the ascent of the oil and lowers the flame. In this case it is not always necessary to extinguish the light in order to trim the wicks; it is usually sufficient to slightly lower them so as to break this crust, and then raise them again, to make a flame of the usual size.

53 If the lamp-chimney breaks, it should be replaced by one of the spare chimneys at hand. In this case, care should be taken to keep the flames low for some minutes, so as not to heat the new chimney too quickly.

Changing the lamp.

54. When an accident to the lamp necessitates the substitution of a spare one during the night, the operation, if it be a *mechanical lamp*, will be performed as follows:

First, place the spare lamp, fitted with its cord and pulley, on the service-gallery, together with the bucket of oil which should be in reserve, (Article 47, § 6.)

Hang the lantern, kept for the purpose in the watch-room, in the interior of the apparatus.

On the staging or the service-gallery place two chimneys, the service-box, the lighting-lantern, and the extra burner fitted with its wicks, if the burner then in use must be changed.

After extinguishing the light of the lamp in use by gradually lowering the wicks, take off the chimney with the precautions above mentioned; wind up the weight entirely, and hold it at the level of the service-table by an iron pin; then unhook the pulley, take the lamp out of the apparatus and substitute the spare one.

This done, fit to the new lamp either the old burner, if it can be used, or the spare burner, after plunging it in oil, and verify the position of the crown by a rapid inspection.

If the crown be not level, the leveling-screws should be used as much as is necessary to bring it approximately to the horizontal position.

Then pour into the lamp the oil contained in the pail.

The spare lamp having thus been set up as rapidly as possible, set it going, and light it as quickly as may be done without breaking the chimney.

The next day the setting up of this lamp should be carefully examined, and rectified if necessary.

55. If the lamp to be changed be a *moderator lamp with weights*, the operations just mentioned will be performed in the same order, taking the following precautions:

Before taking away the lamp to be replaced, the weights must be taken from the piston and the cistern entirely emptied.

To do this, the piston is wound up, and the weights taken off one by one, either by hand or with a hook, then the piston is left to itself, and the lower cock opened, the oil being received into vessels placed for the purpose.

The spare lamp having been rapidly set up, pour all the oil contained in the former lamp into the cistern, close the upper cock on the supply-tube, wind up the piston, place the weights taken from the other lamp upon it, then reopen the cock, and as soon as the oil reaches the burner light it quickly, as above described.

The changing of a *moderator lamp with a spring* is much easier on account of its small size.

56. If the lamp be a *constant-level lamp*, and can be entirely removed from the apparatus without taking it apart, the operation is easy; but in most cases it is necessary to take the lamp apart; then the cistern is taken out, the oil contained in the burner and communicating pipe emptied by means of the cock on that tube; the pipe uniting the cistern and the burner is unscrewed, the burner removed and the spare lamp rapidly substituted. Before placing the new lamp, care should be taken that its screw-joints are well provided with leather washers.

57. The keeper on watch should never proceed to change the lamp without calling a second keeper to assist him.

Precautions to be taken when winding up the motor-weight or piston of the lamp.

58. When, during the course of the night, the weight of the lamp machinery is to be wound up, it is necessary, after every third turn of the key, to turn the key backward for an instant. If this precaution be not taken, the flames will rise during the time that the ascent of oil is interrupted and smoke the chimney.

So also, in moderator lamps, it is necessary to stop several times while winding up the piston, taking care to close the cock on the supply-tube the moment an ascending motion is given to the piston, and to open it again when it stops, so as to prevent the oil from being sucked out of the supply-tube and thus failing for some moments at the burner.

Measures to be taken when oil does not reach the burner.

59. In case the keeper on watch has neglected to look after the lamp, and the supply of oil at the burner fails, he should at once enter the apparatus and accelerate the motion of the pumps by a moderate force applied to the winder, by turning backward with the key.

If it be a moderator lamp, he should unroll the chain from the winder by hand, so as to withdraw as far as possible the movable needle, and if that be not sufficient, he should *unscrew* this needle in the piece which carries it, so as to withdraw it still more. He may finally add a weight or two to those placed on the piston, and in all cases take care to entirely fill the lamp.

Whatever may be the kind of lamp, if these means do not suffice, the keeper will find it necessary to change either the burner or the lamp.

Heater.

60. When the cold is sufficiently intense to congeal colza oil, the following precautions will be observed for mechanical-pump lamps, when preparing for lighting.

1st. An hour before sunset, the oil intended for the lamp will be heated to such a degree that one cannot bear the hand in it, then pour it into the cistern.

2d. Unscrew the burner and pour hot oil through a funnel into the pump-case, then, having held for some moments the burner itself plunged in hot oil, replace and light it.

3d. Prepare and light the lamp of the *two-tubed heater*, and, after tightening the screws of this little apparatus so as to make it perfectly tight, plunge it into the cistern of the lamp.

It is necessary to take care not to raise the wick of the heater-lamp more than 7 millimeters above its burner, for otherwise it may be extinguished by the thick smoke which will be produced.

For moderator lamps, proceed as above as far as regards the temperature to be given to the oil, and to the burner before lighting; then, as these lamps are not adapted to receive a tubular heater, a night-lamp or taper should be placed under the bottom of the lamp, on the side of the tube for the ascent of the oil, and at a sufficient distance not to burn the bottom.

Mineral oil does not congeal and need not be heated during the winter.

## CHAPTER II.

### MORNING DUTIES.

61. The principal morning duties should be performed in the following order: Morning duties.

1st. A quarter of an hour before sunrise the light of the apparatus should be extinguished, commencing, if it be a colza-oil lamp, with the outer wicks and proceeding gradually, so as not to expose the chimney to too sudden a change of temperature. If it be a mineral-oil lamp, stop the ascent of the oil to the burner, lower the wicks and blow out the light. Extinguishing the light.

2d If it be a lamp with an exterior motor-weight, this should be wound up to the height of the service-table, and held there as before described. Winding up the motor-weight of the lamp.

3d. If it be a revolving apparatus, the weight that gives it rotary motion should be wound up, and the main wheel clutched with its bolt; then the bevel-wheels should be put out of gear, so that the clock will not be liable to shocks which might injure it. Winding of the weight of the clock-work.

4th. The lantern curtains should be lowered and the cover placed over the apparatus—two precautions essential, to prevent the rays of the sun from injuring the lamp-burner and the silvering of the lower mirrors. Lowering curtains and replacing cover.

5th. The smoke-funnel, as well as the chimney, should be taken off and placed for the time on the service-table. Taking off the chimney.

6th. The wicks of the lamp should be so trimmed that they will be exactly even with the burner, according to the directions of Article 34. Trimming.

7th. The interior of the burner should be cleaned with a bottle-brush, and the outside of the lamp with a wiping-cloth. Cleaning of the burner and the outside of the lamp.

8th. If the lamp be a mechanical one, the oil should be drawn off into an oil-carrier, and set aside to be strained some hours afterward; the reservoir should be rinsed out with fresh-strained oil, which will afterward be passed through the filter, and the refuse attached to the sides of the cistern wiped out by a piece of clean linen fixed to the end of a small stick. If the strainer of the suction-tube appears to be obstructed, the tube should be taken apart, cleaned, and then returned to its place. The cistern should then be filled with oil strained the day before. Cleaning and refilling the cistern.

If it be a moderator lamp, the reservoir should be emptied immediately after extinguishing the light, therefore the burner only need be cleaned, and the piston should not be wound up until the cistern is filled anew. After filling, care should be taken to entirely close the cock placed on the upper part of the supply-tube.

If it be a constant-level lamp, after having cleaned the body of the lamp, the cistern should be filled, and the cocks and joints examined to see if they are perfectly tight.

9th. The chimney which has been in use should be cleaned with care, according to the directions in Article 80, and placed, together with its smoke-funnel, in one of the cases of the staging or in the closet of the light-room. Cleaning the glass chimney.

10th. The lantern-glass should be wiped within and without, and, if need be, cleaned with whiting or polishing-rouge. Cleaning the lantern-glass.

Renewing the wicks. 62. Whenever the lamp in use has been entirely or partly fitted with new wicks, the lamps must be immediately set running for about an hour, so that the new wicks may become well saturated with oil.

Covering the lamp. 63. Having finished the morning duties as far as the lamp is concerned, it should be re-covered, so as to keep the dust out, until the time for lighting.

# THIRD SECTION.

## DUTIES RELATING TO CARE AND CLEANLINESS.

---

## CHAPTER I.

### CARE OF THE LAMP.

Periodical change of the lamps.

64. When the lamp of an apparatus has been in continuous use for fifteen days it should be replaced by a spare one, and this rotation between the three lamps regularly kept up as long as they are in good working order.

The moderator and constant-level lamps need be changed but once a month.

65. This change will be made in the morning, and the new lamp kept running for some hours to see that it works regularly. Care must be taken to first supply it with oil.

Cleaning lamps after having been in use fifteen days or a month.

66. The lamp taken from the apparatus will be examined and cleaned with care. The pump-case of mechanical lamps should be taken apart to clean out the oil which, if remaining, might after a while hinder the free play of the valves, or incrust the bottom of the lamp, and obstruct the strainer on the end of the supply-tube. This tube should be unscrewed and its strainer cleaned.

For a moderator lamp, the piston will be taken out, the oil emptied from the cistern, and the supply-tube and pieces of the regulator cleaned.

If it be a constant-level lamp, it will be taken apart and carefully cleaned; the cocks will be particularly examined, and, if required, new washers will be put on the joints.

The leathers of mineral-oil lamps should be soaked in fatty oil, in order that they may preserve the necessary flexibility.

67. The lamp, properly put together and covered, will then be put in one of the closets of the watch-room.

Use and preservation of multiple-wick burners.

68. Of the six burners belonging to the three lamps of a light-house, one will be on the lamp in use, mounted and fitted with wicks; another, fitted with *dry wicks*, will be kept in readiness for use in one of the cases of the staging, or in the closet of the light-room. The four others, not fitted with wicks, well-cleaned, dry, and having their racks slightly greased with tallow, will be kept in a closet free from moisture, and will be used only when one of the first two requires to be repaired.

The spare burners should be examined from time to time, and cleaned if need be. It should be particularly noticed whether their racks work freely, and they should be often wiped and greased.

Ordinary care of mechanical lamps.

69. To keep the mechanism of the lamps in good running order a little clock-oil should be put from time to time on the bearings of the movable parts and on the escapement-cams of the *Henry Lepaute lamp*. It should be applied to the bearings of the fly; those of the main wheel and to the endless-screw in the clock-work lamps more frequently than to the other parts. Care should also be taken to apply but a very small quantity of oil, first having wiped away with a stick and a clean linen rag all of the old oil that remains sticking to the various parts of the works.

Finally, for moderator lamps burning colza oil, a quantity of oil should be left in the bottom of the lamp sufficient to moisten the leather of the piston and preserve its flexibility.

In moderator lamps burning mineral oil, the piston should be well cleaned and properly oiled with fatty oil.

Taking apart and complete cleaning of mechanical lamps.

70. Each mechanical lamp should be taken apart and completely cleaned at least once a year, and as much oftener as necessary.

71. To clean the brass of the clock-work, tripoli moistened with spirits of wine should be applied, and it should then be rubbed with a silver-plater's brush until it takes a good polish.

The steel parts should be cleaned with tripoli moistened with a little clock-oil.

Before again putting together the works, the holes for the pivots of the wheels should be cleaned with a small stem of soft wood, as should also the nuts and screw-threads, and especial care should be taken to remove every fragment employed in the cleaning, even to the last grain of tripoli.

Derangement in the mechanism of lamps, and means of remedying it.

72. When a mechanical lamp, after having run regularly for some time, ceases to work well, the keepers should endeavor to discover the cause of the irregularity, in order to remedy it as soon as possible.

To facilitate their search, the principal causes of disturbance which tend to injure the effect of lamps of each kind are here mentioned.

Irregular ascent of oil.

73. When the oil flows irregularly, the flame alternately rises and falls, and cannot be kept at a constant height.

In the old clock-work lamps this might be caused by the pump-rod wheels not being geared so as to cause regular movements of the piston. This may be remedied by replacing the gearing in the position indicated by the marks.

In the escapement lamps, the irregular ascent of the oil may arise from a change in position of the cranks which transmit the motion to the vertical rock-shafts, from a simple loosening of the screws which hold the escapement-levers, or from some alteration in the form of the pieces of the escapement caused by wear.

In the first case, the cranks must be returned to the place indicated by the marks; in the second, the loose screws should be re-tightened; in the third, the lamp sent to Paris for repair.

Clock-work lamps of the new pattern and moderator lamps will probably give no trouble in this respect until the parts are worn by long use.

Stoppage of a valve.

74. In pump lamps one of the valves may cease to work because of the displacement of the steel wire or wire-cloth (if it be a *Wagner* lamp) which holds it, and then it is simply necessary to return it to place.

Play of the valves.

75. When one of these same mechanical lamps in which colza oil is burned has not been used for some time, and the pump-case not been (before setting it away) thoroughly cleaned out, its valves cannot play on account of the sticky quality of the old oil, which adheres to their surfaces.

Valves thus gummed up must be cleaned by washing them in tepid oil, or they must be replaced by new ones, made with the punch furnished for the purpose.

Leather of plunger broken.

76. When one of the leathers of the plunger splits, the ascent of the oil is no longer regular nor sufficient in quantity. An accident of this kind becomes known at once by the loss of oil which results, and is remedied by refitting the plunger with a new leather, properly shaped on a cast-iron mold. If it be a mineral-oil lamp, care should be taken to moisten the calfskin in fatty oil before using it.

Keepers of lenticular apparatus should become accustomed to removing the plunger-leathers of mechanical lamps. Care must be taken not to stretch the leather too tightly over the pump-case, for then the movements of the plunger-rods would be impeded and the supply of oil irregular. There will also be the same difficulty if the leathers are too loose.

If a plunger-leather breaks during the night, and the flame cannot be kept at two-thirds the prescribed height, the lamp must be changed.

Suction-tube obstructed.

77. In case of neglect to change the lamp at the proper time, or to strain the oil before putting it into the cistern, or to clean the wire cloth of the suction-tube at least once a week, the holes in the cloth may become obstructed so as to intercept or at least considerably hinder the ascent of the oil.

In order in such a case to avoid changing the lamp during the night, an attempt may be made to overcome the difficulty by increasing the motor-weight, or opening the fans of the fly in lamps provided with that regulator.

Insufficient or excessive supply of oil to the burner.

78. When the burner of a *mechanical-pump lamp* is not sufficiently supplied with oil the wicks become charred, the flame reddens, rises, and smokes, and if the ascent of the oil entirely ceases, the crown of the burner being no longer cooled, it becomes charred or the solder damaged.

If, on the contrary, too much oil be supplied, it prevents the full development of the flame.

The first disturbance may arise either from the obstruction of the strainer of the supply-tube, which may have been neglected, or from the obstruction of the orifice in the diaphragm of the pump-case. To remedy either difficulty, increase the flow of oil to the burner by turning the screw of the pump-case, whose point penetrates the orifice of the diaphragm, if the lamp be provided with that device, or if not, give with the winding-key a gentle turn backward.

An excess of oil can be reduced in an escapement lamp by turning the screw of the regulator (if there be one) so as to partially close the supply orifice; in clock-work lamps, by opening the fans of the fly; and in all lamps, by diminishing the motor-weight.

Moderator lamps are not exposed to the same derangements, and perhaps require less care, but still it may happen—

*First*, that the wall of the cistern in which the piston moves being dented, the piston may encounter resistance in some parts of its course, and the supply to the burner be for the time insufficient. The keeper ought in this case to dismount the lamp, strike the cistern-wall with a hammer until the dent has disappeared, then return the cistern to its place.

*Second*, that the leather of the piston for some cause or other has become creased, no longer adheres perfectly to the cylinder, and allows the oil to pass it; it therefore runs down much more rapidly than usual; in that case the leather must be removed and a new one substituted. The old leather can be afterward used if the creases can be taken out.

*Third*, that refuse matter has accumulated near the opening of the regulator and the latter does not work satisfactorily. It will then be sufficient to entirely withdraw the needle so as to produce a gush of oil, which will very likely carry away the refuse.

If the obstruction be at the strainer and the lamp cannot be taken apart to thoroughly examine and clean it, a sufficient flow can be obtained either by increasing, as before stated, the delivery of the regulator or by adding weights to the piston.

In the various dismountings and remountings which moderator lamps require, the keepers cannot be too careful to replace with accuracy upon the winder, the female screw which carries the needle of the regulator.

If this piece be placed too far from the center the piston cannot descend to the bottom; if it be placed too near, it cannot be wound up, and in the effort to wind it there will be danger of injuring or breaking some parts of the regulator.

It is in order to avoid this difficulty that some moderator lamps are provided with regulators, in which the needle is independent of the winding-shaft.

The preceding remarks principally relate to moderator lamps with weights.

Moderator lamps with a spring are more easily kept in order, and if, by reason of wear, the incrusting of the piston, or from any accidental cause, one of these lamps ceases to work regularly, it should be sent to Paris to be cleaned and repaired.

In *constant-level lamps* the oil will be regularly fed to the burner if no obstacle to the flow exists between the cistern and the burner, and air can reach the cistern, to take the place of the oil as fast as it is consumed.

Cleaning of the burners and tinware.

79. When a burner is found to be dirty and gummed up, it will be cleaned by dipping and washing it several times in boiling water. In case pure water does not answer, a very weak lye may be used.

The tin vessels and utensils will be cleaned with Spanish whiting mixed with a little fatty oil.

Cleaning the glass chimney.

80. The glass chimneys soiled by smoke, or by drops of burnt oil, will be cleaned by rubbing them, until all spots have disappeared, with a rag or a piece of soft wood dipped in fatty oil, then they will be wiped and polished with whiting. The transparency of the glass will thus be entirely restored.

## CHAPTER II.

### CARE OF THE CLOCK-WORK, THE CHARIOT AND VARIOUS ACCESSORY PARTS, IN LIGHT-HOUSES WITH VARIABLE LIGHTS.*

Ordinary care of revolving machinery of the apparatus.

81. Care should be taken to keep the case containing the revolving machinery of the apparatus as free from dust as possible; the wheels and pivots should be cleaned as often as necessary with a feather-duster and a clean linen cloth.

82. From time to time a little clock-oil should be placed on the pivots of the fly, on the joints of the movable arms of the governor, and on the bearings of the barrel carrying the cord of the motor-weight. The pivots of the other parts should also be oiled, but less frequently. The old thickened oil should also be carefully removed before applying new oil.

83. To prevent the rusting of the parts made of polished iron and steel, they should be rubbed as often as necessary with a rag dipped in neatsfoot oil, tallow, or other unsalted grease. Care should be taken not to get this grease on the copper, bronze or brass work.

Taking apart and complete cleaning of the revolving machinery.

84. Each year, in the month of July, the revolving machinery should be taken to pieces by the keepers and thoroughly cleaned. They will perform this operation in a manner similar to that described for the cleaning of the works of mechanical lamps, (Article 70.)

Testing the motion.

85. After putting all the pieces of the clock together, it will be set running, to see if it works freely with the ordinary weight, and if each revolution of the apparatus takes place in the prescribed time.

In case the motion be too slow or too fast, it can be properly regulated by the fans of the fly.

If the regulator be a governor, the motion can be quickened by raising the movable balls on their stems, or retarded by lowering them.

The variations of the resistance which the revolving frame causes to the machinery, can also be ascertained by the greater or less separation of these balls.

Preservation of the spare fly.

86. The spare fly should be inclosed in a box and put in a dry place. It should be examined from time to time, and the pieces of polished steel greased, taking care each time to wipe them well.

Cleaning of the circular chariot, and the sleeve of the revolving frame, &c.

87. The large and small rollers of the chariot, the rollers of the revolving sleeve, as well as the ways on which they run, should be wiped daily. The pivots of the rollers should be cleaned and oiled as often as necessary.

Taking apart the circular chariot.

88. When it is required to take apart the circular chariot of the movable frame in order to clean it, the frame should be raised some millimeters by three small jack-screws, specially provided for this purpose, and these should be successively replaced by regularly squared blocks of wood. This done, the outer rollers will be taken off, then the pins of the tenons of the iron chariot circle removed, and its two pieces separated, care being taken not to bend the pivots.

This operation, as well as the setting up of the chariot, requires two keepers.

*Only the last two articles of this chapter relate to the duties of keepers who have charge of fixed lights.

Care of the jack-screws by which the movable frame is raised, and of the other iron and steel tools.

89. The three jack-screws intended for raising, when necessary, the movable frame, should be constantly kept in good condition, and ready for use, as should all other tools and utensils.

Those iron or steel tools and utensils which are only occasionally used, should be kept constantly greased with tallow, and be put away in a dry closet.

Care of the oil-strainers.

90. Besides the ordinary cleaning, the oil-strainer should receive special attention. Every month the piece of cloth which rests on the strainer should be washed with soap, and the sand washed in boiling water. It will not be replaced until perfectly dry; to effect this, it should be heated in a vessel.

Sea-sand must never be used, even after it is washed in fresh water.

In case sand of the proper quality cannot be for the time obtained, a piece of filtering paper may be placed on the cloth.

In some cases the employment of the filtering paper will permit the utilization of residues of oil that would otherwise be rejected.

## CHAPTER III.

### CARE OF THE LENSES, CATADIOPTRIC RINGS AND MIRRORS.

Daily cleaning of the apparatus.

91. Each day the lenses, catadioptric rings and mirrors should be dusted, and when necessary, they must be wiped with a soft clean linen cloth.

If these pieces should be wiped before being dusted, they might be scratched.

92. If any part of the surface of the lenses, rings or mirrors be found spotted with oil, they should at once be cleaned with a linen cloth saturated with spirits of wine.

Washing in spirits of wine.

93. Every two months the entire surface of the lenticular pieces and mirrors should be washed with spirits of wine, after which, each one will be wiped as just directed.

Preservation of the polish.

91. These same parts should be polished with rouge once a year. This operation will be performed in the following manner:

Use of the polishing-rouge called English rouge.

95. A small quantity of the rouge (15 grammes for instance) will be mixed with water until it forms a smooth paste. This paste will then be diluted with about a pint of water, and after being well stirred with a small stick, it should be left a few moments to settle. The liquid will then be decanted, by pouring it gently into another vessel, to free it of any gritty particles it might contain, which will remain in the bottom of the first vessel. This being done, it should be left to stand for about half an hour, then the water poured out till the rouge appears at the edge of the vessel.

A light coat of this liquid rouge will be spread, by means of a sash-brush or a soft linen cloth, on the entire surface of the glass.

When this coating has dried, it should be rubbed with a chamois skin until the rouge is entirely removed.

The rouge thus prepared should all be used, as the remainder is not suitable for another cleaning.

Preservation of the polishing-rouge.

96. The polishing-rouge should be carefully inclosed in a box, and put where no dust can reach it. If it be not soft to the touch, it should not be used, as it might injure the polish of the glass instead of improving it.

Care of metallic reflectors.

97. Metallic reflectors should be polished every two months with rouge prepared as above described.

They should be wiped every morning with a soft linen cloth, and then smartly rubbed with the chamois skin used for removing the rouge. This skin should be carefully kept free from dust and dampness.

## CHAPTER IV.

### CARE OF THE GLASS AND PUTTY OF THE LANTERN.

Daily cleaning of the lantern-glass.

98. The glass of the lantern should always be kept perfectly clean: to effect this, it should be wiped on the inside every day with a linen cloth, and in the same way on the outside, if necessary.

The spots which remain on the glass after this cleaning should be removed by a little water or spirits of wine.

Preservation of the polish of the lantern-glass.

99. Beside the daily cleanings, the lantern-glass should be polished from time to time with whiting, and once a year with polishing-rouge, outside and in, taking the same precautions indicated for the cleaning of the lenses.

Preservation of the putty-joints.

100. The putty-joints of the lantern-frame, and all the joints by which rain-water might enter, should be carefully attended to.

The putty will be made of two parts whiting and one part white lead, the whole pulverized, and well mixed, rather stiff, with equal parts of boiled and raw linseed oil.

Renewing broken panes.

101. As light-keepers may sometimes have to replace broken panes themselves, some details are here given on the subject.

Cutting the glass.

102. The glass is cut with a diamond like that used by glaziers, only somewhat stronger.

To detach the piece after having marked it off with the diamond, tap the other side of the glass with the handle of the tool, commencing at one end and following the scratch. The crack is thus made larger, and a slight effort, as if to bend the glass back and forth, will detach the strip to be removed.

If the cut shows some inequalities, they can be removed by the *glazier's pincers*, a kind of pincers with long rounded claws.

Grinding the glass.

103. The glass thus cut to the required size should be ground obliquely on the two sides and square on the horizontal joints.

This is done by rubbing the glass on a cast-iron plate, covered with sharp sand moistened with water, and renewed from time to time.

Setting the glass.

104. It is very essential that, when the glass is put in place, a space of about two millimeters should be left at each edge. If placed flush against the frame, it will be liable to break during storms by reason of the oscillation of the lantern; and if less than two millimeters was left between two panes that come one over the other, the putty would not hold in such a narrow joint.

The panes are set upon little leaden wedges.

When the glass in a sash composed of several superposed panes is to be reset, it is necessary, in order to replace a lower or middle pane, to remove all the panes above it in the same sash.

To putty the joint between two panes, put a coat of putty five or six millimeters thick on the lower edge, place on it two little leaden wedges bent V-shape; then place the upper frame, which by its weight will press out the putty where it exceeds the wedge in thickness. These wedges should afterward be cut off flush with the panes.

The putty attaching the panes to the sash should reach the edge of the slats. In replacing the exterior slats, a little putty should be put under the head of each screw which holds them.

# CHAPTER V.

## UTENSILS, TOOLS AND VARIOUS ARTICLES USED ABOUT THE APPARATUS AND LANTERN.

### TINWARE.

105. An oil-pump is used to transfer the oil from the casks to the receptacles intended for it, and from those receptacles to the oil-carriers. Oil-pump.

106. The oil-strainer is in two parts; the upper is the strainer proper, the lower is a vessel to receive the strained oil, and is provided with a cock. Oil-strainer.

The strainer proper is a tin plate pierced with holes; on it is placed a piece of cloth, and a layer of fine sand two to three centimeters in thickness.

This apparatus should be placed on a stand or little wooden table, of such height that an oil-carrier can be placed under the cock.

107. The copper oil-carriers and the tin cans are exclusively used for transporting oil in the interior of the light house Copper oil-carriers and tin cans.

For mineral oil, care must be taken to keep the cans tightly closed.

108. In light-houses where colza oil is used, the lighting-lantern contains, besides a stationary lamp, two little hand-lamps, called *lucernes*, which are used for lighting up. Lighting-lanterns.

At the middle of the lucerne is a copper screw-button, which can be taken off to put in the oil and wick. Near the ring which serves as a handle is an air-tube, on which the thumb is placed to prevent the oil from running out when it is tipped forward to light the wicks of the large lamps.

109. The heater of mechanical lamps burning colza oil is a little lamp shut in an oblong box with two tubes. Two-tubed heater.

On one of the sides of this box a hole is made by which the lamp can be put in. It can be tightly closed by a screw-button and washer.

110. The service-box has a transverse handle, and a cover with two lids. Service-box fitted up.

It is divided into three compartments.

The first receives a flat tray, on which are temporarily placed the greasy rags and the trimmings from the wicks; under this tray are placed the clean rags for wiping the glass chimneys.

The second should contain the following articles:

1st. A *triangular scraper*, for removing burned oil sticking to the edges of the burner.
2d. A *horse-hair bottle-brush*, for cleaning the lamp and the air-tubes of the burner.
3d. A pair of *curved scissors*, for trimming the wicks.

The third compartment is intended to hold—

1st. A pair of *straight scissors*, to cut the wicks to a proper length before placing them on the burner.

2d. A *measure*, which shows that length.

3d. The *mandrels* required for fitting the wicks. These are conical in form, except a small cylindrical rebate at the bottom, intended to hold the wick-carrier.

Dripping-pan with a movable strainer.

111. The dripping-pan with a movable strainer is a square flat vessel with a double bottom. The upper one is movable and pierced with holes; the other has a little pipe for drawing off the liquid.

It is used for draining the burner when just removed from the lamp, the lamp-fillers, the oil-measures, &c.

Two hundred and fifty grammes measure.

112. The 250 grammes measure is used for ascertaining the quantity of colza oil which overflows from the burner, as described in Article 37, so that the supply may be regulated as prescribed by Article 16.

Lamp-fillers.

113. The lamp-fillers, containing from 1 to 5 kilogrammes of oil, are used for filling the small lamps and lanterns.

Rouge-box.

114. The polishing-rouge should be carefully protected from dust. For this reason it is shut in a double box. Above the smaller one is placed the chamois skin used to rub the pieces coated with polishing-rouge.

Common lantern with lamp.

115. The keeper on watch should always see that the lantern that must be hung in the interior of the apparatus, if it becomes necessary to extinguish the service-lamp, either to change or trim it, is in the watch-room, ready to be lighted.

Keeper's lamp.

116. Some of the lamps intended for the special use of the keepers are pump-lamps; small constant-level or moderator lamps are now being substituted for them.

In light-houses where mineral oil is used the keeper's lamps have a flat wick. When one of these lamps is lighted the wick must be always kept below the capsule which covers the wick-sheath. By raising or lowering the wick so that it may burn nearer or further from the edge of the hole cut in this capsule, the flame may be regulated.

## INSTRUMENTS AND TOOLS.

Oil-gauges.

117. The gauges, 30 centimeters long, with divisions showing centimeters and millimeters, are used for measuring the height of the oil in the cisterns of the mechanical lamps, and therefrom to ascertain the weight of this oil by means of the gauging-table of the lamps.

Jack-screws.

118. The jack-screws, three in number, of iron or bronze, are specially intended to raise, when necessary, the movable frame of revolving apparatus.

Each jack-screw is formed of a stem or bolt, the ends of which, cut with screw-threads running in opposite directions, screw into two little movable nut-plates. The stem is enlarged in the middle and pierced with holes, into which a lever is passed to work it.

Spirit-level.

119. All light-houses are furnished with a small spirit-level, which is to be used to verify the level of the crown of the burner of the lamp. Another, larger level, is supplied to light-houses having revolving apparatus, to verify the horizontal position of the surface on which the chariot moves, and also the level of the wheel which communicates the motion of the rotary machine.

Instruments for testing mineral oil.

120. Each light-house where mineral oil is used receives a box containing the necessary instruments for testing that oil.

These instruments are—an areometer and a test-glass for ascertaining the specific gravity; a thermometer for showing the temperature of the liquid under experiment; a special apparatus for determining the flashing point, consisting of a little copper vessel which is placed full of water over a spirit-lamp, and into which sets a copper capsule wherein is placed the oil to be tested.

The use of these various instruments is explained in Chapter II, Article 23.

121. The molds for making plunger and piston-leathers consist of two cast-iron pieces forming a sort of matrix, by means of which a proper shape is given to the plunger-leathers of the feed-pumps and the piston-leathers of moderator-lamps. Mold for plunger and piston-leathers.

122. This is a steel instrument, with which the leather valves used in the pump-case of mechanical lamps and the leather washers for joints are made. Punch.

123. A pair of straight and two pairs of curved scissors are supplied to each light-house. These scissors are principally used for cutting and trimming the wicks. Straight and curv'd scissors.

124. Triangular scrapers are used for cleaning the burners, as before stated. Triangular scrapers.

125. Glazier's pincers may be required when a lantern-pane is to be replaced. Glazier's pincers.

To slightly reduce the size of a pane, place the pincers so that the claws may seize the edge and yet make a very acute angle with it; by bearing a little on the handle of the pincers, turning the hand outward, small particles of glass will splinter off. This should be done very slowly and with much caution, care being taken to remove but a little glass at a time.

126. This key is of polished steel, and should be exclusively used for winding and unwinding the clock-work of the revolving machinery. Winding-key of the revolving machinery.

127. All these tools are indispensable, either for taking apart and putting together the mechanical lamps and the clock-work, or for making pins when required, or soldering leaks in the cupola of the lantern and tin vessels, &c. Hammers, pincers, monkey-wrench, files, vises, pliers, screw-drivers, and sold'g-irons.

128. The wrenches and screw-drivers that have been used for setting up the lantern, the illuminating apparatus, the service-gallery and its step, the cast-iron stairways and the balustrade of the lantern, as well as the spare bolts, screws and nuts, will be left at the light-house, and should be preserved with care.* Wrenches and screw-drivers which have been used in setting up spare nuts and bolts.

BRUSHES.

129. The long-handled horse-hair brushes are used for sweeping the various rooms and stairways of the interior of the light-house. Long-handled brushes.

130. The wolf's-head is a round long-handled horse-hair brush, used for cleaning ceilings and staircases of the tower. Wolf's-head.

131. The feather dusters should only be used to dust the illuminating apparatus and the glass of the lantern. Feather dusters.

The optical parts of the apparatus should always be dusted before wiping them.

132. These brushes, which have handles and long bristles, are used for sweeping the service-table, the service-gallery and the step. Counter brushes.

133. These brushes also have handles, but they are smaller and the bristles are shorter than the preceding. They are used to clean the lamp, the clock-work and the utensils, and to remove whiting and tripoli, which without them it would be difficult to remove from holes and deep recesses. Silver-plater's brushes.

134. These are used to paint the iron work of the lantern and illuminating apparatus, and one of them should be kept to spread rouge on the surface of the optical pieces and the glass of the lantern. Sash-brushes.

135. The bottle-brushes are made of bristles mounted on a wire stem; they are used to clean the burners. Bottle-brushes.

*Other tools furnished for setting up lanterns and illuminating apparatus may yet remain in light-houses and be borne on their inventories, but they are not indispensable and should not be renewed.

Calf-skin. 136. Calf-skin is used to make plunger-leathers, valves, and washers.

Chamois skin. 137. The chamois skins should be used only for rubbing the parts covered with polishing rouge, and the reflectors.

Clock and neats-foot oil. 138. The clock-oil is intended to be exclusively used for oiling the clock-work; neats-foot oil is used for mixing with the tripoli for cleaning the steel pieces of the clock-work, and for greasing the polished iron parts of the frame of the apparatus.

Spirits of wine. 139. Spirits of wine is used:

1st. To wash the optical parts of the apparatus, and to remove from those parts or from the glass of the lantern fatty bodies and spots which cannot be easily rubbed off.

2d. To mix with the tripoli used to clean the copper utensils and parts of the clock-work.

Copperas water. 140. The copperas water is principally used for cleaning the bronze frame of the apparatus.

Polishing-rouge. 141. The polishing-rouge is specially employed in the operation which must be performed once a year at least, and which has for its object the preservation of the polish of the glass of the apparatus and of the lantern.

For this purpose it must be prepared with the greatest care in the manner stated in Article 95.

Spanish and shell white. 142. Whiting prepared in the same way and with the same care as polishing-rouge serves for cleaning the glass of the lantern and the windows of the tower and dwelling.

Mixed with oil it is used to clean the tinware.

It is also used in mixing putty for the windows of the lantern.

The shell white is employed either with the copperas water or mixed with ordinary water, to clean and polish the copper.

Tripoli. 143. The tripoli is used in the manner and for the purposes mentioned in Articles 138 and 139.

Boiled linseed oil, raw oil and white lead. 144. The ordinary supplies of raw linseed oil, boiled oil and white lead, are intended to be used with whiting for making the putty required for glazing the lantern, as prescribed in Article 100.

Examined and completed by the Engineer-in-Chief
of the Central Light and Buoy Service.

Paris, February 8, 1872.

E. ALLARD.

Examined and forwarded by the Inspector General of Bridges and Roads, Director of the Light and Buoy Service.

Paris, February 12, 1872.

L. REYNAUD.

EXAMINED AND APPROVED:

Paris, February 26, 1872.

*The Minister of Public Works,*

DE LARCY.

# INSTRUCTIONS

RELATIVE TO THE

# SERVICE OF LIGHTS OF THE LOWER ORDERS.

---

## CHAPTER I.

### GENERAL REMARKS.

Illuminating apparatus.

1. The illuminating apparatus for lights of the lower orders or harbor lights are variously arranged. Those most in use are:

1st. The *catadioptric apparatus*, 0.375 or 0.3 of a meter interior diameter, lighted by a constant-level lamp, by a mechanical lamp, or a lamp with a cistern set below, and of variable level.

2d. The *lenticular apparatus of pressed glass*, lighted by a constant-level lamp.

3d. The *parabolic reflector or photophore*, lighted by a constant-level lamp.

4th. The apparatus with two parabolic surfaces or *sideral apparatus*, lighted by a constant-level lamp.

The constant-level lamps of the catadioptric apparatus and photophores burn either colza, schist oil or petroleum.* The lamps which have the cistern below and no works are only adapted for burning schist oil.

2. The catadioptric apparatus are set on cast-iron pedestals or tripods. They are usually fixed to a central point, and rest on rollers, so that each one can be easily turned around its axis.

The three other kinds of apparatus are sometimes set in a like manner; but generally they are put in a small movable lantern, which is hoisted or lowered in an iron frame.

Constant-level lamps.

3. The constant-level lamps are in two parts—the lamp-body and the cistern. The cistern has in its lower part a lift-valve, which is raised when the stem it carries strikes the bottom of the lamp-case. Communication is thus opened between the cistern and the burner.

To secure regular feeding from the cistern, it is necessary, when colza oil is used—

1st. That the end of the cistern-tube should be some millimeters lower than the crown of the burner.

2d. That the external air should have free access to the lower orifice of the cistern, to replace the oil as fast as it is consumed; for this purpose an opening is made in the lamp-case.

In lamps for burning schist oil, the lower end of the pipe should be about 6 centimeters below the crown of the burner.

* There is no essential difference between these last two oils except in their production, and it should be understood that what is hereafter said of schist oil applies equally to petroleum.

Lamps of catadioptric apparatus and photophores.

4. The burners of colza-oil lamps used for lighting catadioptric apparatus and photophores are provided with a chimney with a shoulder. The foot of the chimney fits into a movable gallery which can be raised or lowered at will, and which is usually formed of two concentric casings. It holds the chimney with a gentle pressure, which may be increased, if required, by slightly bending inward, with flat pincers, the elastic blades of the exterior casing.

In the schist-oil lamps, the gallery which carries the chimney may be turned, but its height with reference to the burner is invariable.

Height of the flame.

5. The height of the flame giving the best effect in colza-oil lamps is 37 to 45 millimeters. It is obtained by raising to a proper height the movable gallery which carries the chimney. If that height be exceeded, the flame becomes elongated, but it will be dull and reddish; if the contrary error be committed, the flame will keep white, but will not reach the desired height.

6. The flame of schist-oil lamps should be kept much lower, and never exceed about 20 millimeters. It can only be regulated by properly lowering or raising the wick; still, when points are found in the flame at certain places in the circumference, they may be sometimes made to disappear by simply turning the chimney. As it is never exactly centered on the burner, it may happen that the slight irregularities it presents will cause the points of flame to disappear.

Consumption of oil.

7. Two sizes of burners are in use in these various lamps—one 24 and the other 21 millimeters in diameter, measuring to the middle of the annular space occupied by the wick. The mean consumption of colza or schist oil is estimated at 60 grammes per hour for the large burner and 50 grammes for the small one.

A few catadioptric apparatus are illuminated with constant-level lamps burning colza oil, and are provided with a burner having two concentric wicks. The general arrangement of these lamps is the same as the preceding, and they consume about 110 grammes of oil per hour. The diameter of the outer wick is 32 millimeters; that of the inner, 16 millimeters.

Filling the reservoir.

8 To fill a constant-level lamp with oil, withdraw the cistern from its case, invert and fill it through the hole in the bottom; then replace it, taking care to close the lift-valve by means of the little stem attached to it, so as not to spill any oil when the cistern is turned right side up. This precaution is especially necessary in schist-oil lamps.

9. To place a wick, raise the wick-carrier as high as possible; withdraw it, and put it on the tin or wooden mandrel; then draw the wick over as far as the wick-carrier, and fasten it thereto by means of the tin ring designed for the purpose. If there be no ring use a thread.

It is essential that the lower edge of the wick should be evenly cut and smoothly covered, so that there may be no wrinkles which would intercept the flow of oil.

The wick being placed, it is lowered as far as possible, and with sharp-curved scissors the upper edge is cut off flush with the burner as evenly as possible.

Trimming.

10. To trim a wick which has been used, raise it to such a height that the charred portion will touch the edge of the burner; then cut it as has just been described.

If it be a schist-oil lamp, it will be necessary before trimming to take out the disk or button in the center of the burner, taking care to replace it when the trimming is finished.

As the flame produced by schist oil is very liable to smoke, it is essential that the most minute attention should be given to the trimming of lamps burning it, so that there may be left on the edge of the wick no inequality and no foreign substance of a nature to produce points.

11. When the temperature is so low that it is feared the oil may congeal, a heater should be placed under the lamp-body. Heater.

This apparatus consists of a cup which is filled with oil, and in which is placed a night-taper with floats. It is fixed by means of the upper ring of its support, below the lamp-body, instead of the movable bottom-piece of the lamp.

This precaution is unnecessary for lamps burning schist oil, as that liquid is not liable to congeal.

12. The lamps of sideral apparatus differ from those which have just been described in the following respects: Lamps of sideral apparatus.

1st. The wick instead of being fixed at its lower edge, is free in a double open-work case, from which it should protrude 4 or 5 millimeters; this case is called the *wick-carrier*.

2d. The chimney, nearly cylindrical in form, is held at about 12 millimeters above the burner by two supports and two elastic rings fixed to a vertical rod.

3d. The heater is a strip of iron, the lower part of which rests in a sheath fixed on the cistern; the upper portion is curved and ends above the chimney.

13. These lamps always burn colza oil. The burner is 20 millimeters in diameter, mean consumption per hour 45 grammes, and the full height of the flame about 40 millimeters. Consumption of oil.

14. The cistern of these lamps is filled in the same way as those just described. Filling the cistern, placing and trimming the wicks.

To set a wick, after cutting it to the desired length by a tin pattern, slide it between the two cylinders by means of a mandrel placed on the wick-carrier, then lower it as far as possible. Trim it evenly with the curved scissors; then raise it to 7 or 8 millimeters above the burner by means of the lifter, which has four blades; the other end of the same instrument is used to return it to the proper height, viz, about 4 millimeters above the top of the burner.

When it is necessary to trim a wick first raise it with the lifter, then having cut it, return it to place, as has been described.

15. As a constant-level lamp cannot illumine the entire horizon, recourse is had. in apparatus where that condition is to be fulfilled, to mechanical lamps, or simply to lamps with a cistern below, and a variable level if schist oil is to be used. Lamps illuminating the entire horizon.

All these lamps are treated in the same manner as ordinary constant-level lamps, so far as regards the chimneys and the placing and trimming of wicks, described above in Articles 9 and 10. Chimneys, placing and trimming the wicks.

16. The mechanical lamps employed for small lights are *moderator lamps*. Mechanical lamps, called moderator.

The mechanism is placed in the lamp-cistern, and consists of a spiral spring, the base of which is fixed to a piston.

The piston, formed of a sheet-iron disk, is provided with a leather washer, and the tube which supplies the burner passes through it. The foot of the rack which compresses this spring is fixed to the piston.

The lower part of the burner is provided with a tube having a leather collar at its base, and an iron stem which penetrates the tube traversing the piston.

To wind up one of these lamps, turn the key placed at the height of the pinion, which works the rack until a stop is reached. This should be done immediately after lighting up, and renewed after the light has been burning six hours.

17. A moderator lamp is filled as follows: Filling the cistern.

The movable case which carries the chimney and the neck are removed, and oil poured in through the opening of the lamp until it reaches the upper part of the cistern.

18. In order that an illuminating apparatus should produce its full effect, it is necessary that the axis should be horizontal and the flame should be placed at the focus. Centering the burners.

In sideral apparatus and in photophores the burner is so fixed as regards the focus of the apparatus, that its displacement need not be feared ; but it is essential to ascertain from time to time that the axis of the apparatus is horizontal. This is shown by a plumb-line suspended at the upper edge of the reflector.

In catadioptric apparatus, it is necessary to ascertain if the burner be placed exactly in the axis of the apparatus and at the proper distance below the focus, viz, 22 millimeters. To do this stretch two threads crosswise, by means of two little copper buttons placed on the inside of the uprights. If the burner be properly set its center will correspond with the point where these threads cross each other, and the top will just graze these threads in apparatus where the buttons are placed at 22 millimeters below the focal plane, or will be at that distance below the threads when the buttons are placed in the middle of the uprights of the apparatus.

When the lamp which lights the apparatus is fed with schist oil, the center of the upper face of the fixed disk placed on the burner must be found exactly at the crossing of the threads, these being stretched at the height of the focal plane

**Lighting the lamps.**

19. To light a colza-oil lamp, raise the wick about 10 millimeters above the burner and light it at two opposite points of its circumference by means of the *hand lucerne*. As soon as the flame commences to rise, and before it gives out smoke, lower the wick and put on the chimney. The wick must be at first kept low, and the chimney high, then successively the former is raised to its proper height, and the latter lowered so as to obtain a regular white and well-developed flame.

These directions are not applicable to the constant-level lamp of sideral apparatus, for, as stated in Article 12, the wicks of these lamps are fixed in a wick-carrier at the proper height. It is only required to raise the chimney about 60 millimeters above the burner, then to lower it, as soon as the wicks have been lighted, until it rests on its support.

In lamps with two concentric wicks, light the central wick first, then immediately lower it as far as possible without putting it out, then light the outer wick ; proceed gradually to raise the wicks and to lower the chimney. About half an hour is required to obtain the full development of the flame of a two-wick burner.

When the lamp burns schist oil, it is sufficient to raise the wick 2 millimeters above the burner, for it is quickly lighted around its whole circumference.

As soon as it is lighted it should be lowered gradually, so that the flame should not at first rise higher than the edge of the disk, viz, about 11 millimeters.

Not before the end of an hour, when the burner becomes heated, does the flame attain its full size, and it will certainly smoke if not kept sufficiently low when first lighted.

**Extinguishing the lights.**

20. In a sideral apparatus, the light is extinguished by lowering the wick or by blowing on it ; for two-wick lamps, commence with the outer wick. The chimney should not be taken off until a few moments after, when it will be sufficiently cooled to prevent its breaking.

**Clock-work.**

21. Some small catadioptric lights are varied by flashes. This characteristic is given by means of lenses with vertical elements, which are revolved around the apparatus by means of clock-work machinery.

The movement of this machinery or mechanism is regulated by a fly, and is put in motion by a weight. It is accelerated or retarded either by closing or opening the fans of the fly, or by increasing or diminishing the motor-weight.

The motion is communicated to the chariot which carries the two movable lenses by means of two cog-wheels, which can be thrown into and out of gear at will.

## CHAPTER II.

### DUTIES CONNECTED WITH THE LIGHTING.

22. Every morning, at daybreak, the keeper should ascend to the lantern and proceed with his duties, as follows: Morning duties.

If the apparatus is revolving, the motor-weight of the clock-work will be entirely wound up and fastened, the work stopped, and the wheel which communicates motion thrown out of gear.

If the lamp be mounted in the apparatus on a movable table, that table will be lowered.

If the apparatus be hoisted on a bracket, it will be lowered until it rests on the service-table intended to receive it.

The light will be extinguished, observing the precautions mentioned above, and the chimney will be wiped with care within and without, then wrapped in a dry cloth and placed where it will be free from dust

The lamp will be removed from the apparatus, and, if it be a constant-level one, placed on its service-stand.

The apparatus will be dusted with the feather-brush, and wiped with a soft linen cloth that is free from dust. If any part be spotted with oil, it will be washed with a little spirits of wine.

The apparatus will then be covered with its linen cover.

The glass of the lantern will be carefully wiped within and without, and, if necessary, cleaned with whiting, or, if necessary, with polishing-rouge.

If the lantern be provided with curtains, they will be hung in place.

The service-table, the pedestal and the interior part of the lantern wall will be dusted, and the staircase swept.

This done, the lamp will be taken into the store-room and weighed to ascertain the amount of oil consumed during the night; then it will be emptied, and the oil poured into the strainer.

The oil which has fallen into the drip-cup during the night will be placed in the vessel kept for leavings, and will be reserved for the use of the keeper.

The burner will be cleaned with care within and without. The burned oil attached to its edges will be removed with the triangular scraper; a bottle-brush will be passed through the interior air-tube, and the outside wiped with a linen cloth.

The buttons of the lamps burning schist oil will be carefully wiped.

The body of the lamp will be wiped and cleaned.

Finally, the lamp will be filled, the wick trimmed or replaced, and the lamp again set in the apparatus, so that every thing may be ready for lighting up at evening.

Care will be taken that the spare lamp, which should be in the light-room, is in a serviceable condition.

If the apparatus be sideral, two extra wick-carriers, provided with their wicks, should be ready to be placed in the lamp.

A can filled with strained oil will be carried up into the lantern, or placed at the foot of the pedestal, to be poured into the spare lamp if required.

23. Every evening at sunset, the keeper will ascend into the lantern, after having provided himself with a lighted lucerne. Evening duties.

If the morning duties have been regularly performed, the following state of things will appear:

The lamp of the apparatus will be in place and ready to be lighted; its chimney will be in the service-closet, as will the extra lamp, the burner, the two chimneys, and the service-box containing the various utensils The weight of the revolving machinery in lights varied by flashes will be found entirely wound up, the main wheel held by its bolt, and the wheels which communicate the motion out of gear.

The cover of the apparatus will be removed, and the lighting commenced half an hour after sunset, so that the light may be at its full brilliancy by nightfall, and in this operation the directions just given will be followed. If the apparatus be on rollers, it will be placed in the position it ought to occupy during the night, and kept there by means of a stop-bolt

At nightfall the curtains of the lantern will be removed, folded and placed in the service-closet, if the apparatus be contained in a fixed lantern.

If the apparatus be in a movable lantern, this will be hoisted to the full height of the scaffold or the pedestal.

If the apparatus shows a variable light, the revolving machinery will be put in motion immediately after lighting. To do this it is sufficient to gear the cog-wheels, withdraw the bolt of the main wheel, and remove the pin which holds the motor-weight.

When the cold is so intense that colza oil will congeal, the following precautions will be taken before lighting:

1st. An hour before sunset the lamp will be taken down and emptied, and the oil heated until too hot for the hand to be held in it; after which the burner will be plunged in it and kept there some moments; it will then be restored to place, and the oil poured back into the lamp.

2d. The heater will be got ready and put in place.

Night duties.

24. From April 1st to October 1st, the light will be visited by the keeper at least once every night, and during the remainder of the year twice every night, and oftener, if from any cause there may be reason to fear that the light may go out or decrease much in intensity.

These nocturnal visits will be made during the summer at about midnight; in the winter at about 11 p. m. and 2 a. m. At each visit the keeper will carry the lighting-lamp.

When the keeper sees that the wick is charred, and should be trimmed or cleaned, he will proceed as follows, according to the kind of lamp.

If it be a constant-level or mechanical lamp, he will immediately replace it with the spare lamp, having filled this with oil and lighted it outside the apparatus. If it be a lamp belonging to sideral apparatus, he will remove the wick-carrier and replace it with one of the spare ones, which he will immediately light. All these operations should be performed as quickly as possible.

Having properly placed the new lamp, the one taken from the apparatus will be set on the service-table, and then trimmed so that it may be returned to place if necessary.

The piston of the moderator lamp should be wound up at each visit.

When the apparatus is lighted by a schist-oil lamp with a cistern below, care should be taken to change the service-lamp toward the middle of the night, lighting the extra lamp before putting it in place.

In no case should oil be poured into a schist-oil lamp while it is lighted.

## CHAPTER III.

### DUTIES RELATING TO CARE AND CLEANLINESS.

Care of the edifice.

25. All parts of the edifice should be kept perfectly clean; they will be swept and dusted every day, and washed as often as necessary

Lantern-glass.

26. The lantern-glass will be wiped every day within and without; once a week it will be washed on the outside.

This glass will be polished with rouge at least once a year; this operation will be performed as follows:

Preparation of polishing-rouge.

27. A small quantity of the rouge (15 grammes for instance) will be crushed and moistened with water until it forms a smooth paste. This paste will be mixed with about a pint of water, and after stirring it well with a little stick it will be left a few moments to settle. The liquid will afterward be decanted, by pouring it gently into another vessel to free it from any gritty particles it may contain. This being done, it should be left to stand for about half an hour, then the water poured off until the rouge appears at the edge of the vessel.

A light coat of this liquid rouge will be spread, by means of a sash-brush or a soft linen cloth, on the entire surface of the glass to be cleaned.

When this coat is dry, it should be rubbed with a chamois skin until the rouge is entirely removed.

Preparation of whiting.

28. The whiting used in the ordinary cleaning of the lantern-glass will be prepared in the same way as polishing-rouge, but in greater quantity, as may be required

Care of the putty joints.

29. The putty of the sashes and all the joints of the lantern by which water can penetrate should receive careful attention

Composition of the putty.

30. The putty used for this purpose will be composed of two parts of whiting and one of white lead, the whole pulverized and well mixed, rather stiff, with equal parts of boiled and raw linseed oil.

Replacing broken panes.

31. As the keepers of small lights may find it necessary sometimes to replace a broken pane, the manner of doing it is thus described.

After having removed the outside fastening strips and the broken glass, the rebates in the frame will be cleaned of any putty which may adhere to them.

The new pane will be applied to the frame so as to make sure that it will not touch the casing at any point, but have a play of at least from 2 to 3 millimeters all around, especially around the notches in the heads of the fixed bolts near the uprights.

If any part of the glass comes in contact with the frame a glazier's pincers will be used to reduce it to the required size, taking care to remove with these pincers only small pieces of glass at a time This operation being repeated, if necessary, along the entire length of the raised part will give the necessary play to the glass.

The casing should receive a coat of spirits of turpentine, and then the putty laid on. On the bottom piece there should be placed three small soft-wood wedges from 2 to 3 millimeters in thickness, one in the middle, the other two about 10 centimeters from the uprights. Without this precaution the glass would, by its weight, force the putty out and then come in contact with the hard frame. Wedges of the same thickness should be placed on the putty along the uprights, and between two panes whose edges meet.

The covering strips will be replaced and the frame puttied.

The putty will be trimmed off even with the vertical strips and the upper transverse piece, and beveled at the bottom to allow water to run off.

Catadioptric apparatus.

32. If any part of the putty of the rings or prisms of the apparatus needs repairing, it should be done immediately, with new putty, as just described.

Every month all the glass surfaces will be washed with spirits of wine.

The apparatus will be polished with rouge once a year.

This will be done as described in Article 27.

Metallic reflectors.

33. Metallic reflectors will be polished every two months, with rouge prepared as before described.

They will be wiped every morning with a soft linen cloth, then smartly rubbed with the chamois skin which was used for removing the rouge. This skin should be carefully kept free from dust or moisture.

Lamps.

34. Every fortnight the service-lamp of the apparatus will be replaced by one of the spare lamps.

Copper constant-level lamps.

35. If a burner becomes unserviceable by reason of wear or accident, it should be immediately replaced by one of the spare burners. This can easily be done by unscrewing the joint. Before placing the new burner, be sure that the joint is provided with a leather washer.

Level of the oil.

36 The level of the oil in the new burner will be verified. It should be about 3 millimeters below the upper edge for lamps burning colza oil.

If the level be too high the oil will overflow; if, on the contrary, it be too low, the flame will come too near the burner and its edge soon burned

When the level is too high, a little plate of tin may be soldered over the notch in the cylinder, which is placed at the bottom of the cistern, and a new notch cut with a file, care being taken not to cut it as deep as the former.

When the level is too low, cut the notch deeper.

In schist-oil lamps the level of the oil should be kept at 6 centimeters below the crown of the burner.

Cleaning.

37. All the copper parts of the lamp should be cleaned every week with tripoli moistened with spirits of wine.

When a lamp is removed from the apparatus to be put in the store-room, the wick should be removed, the lamp emptied and drained, and then cleaned outside with tripoli.

The inside will be cleaned by rinsing it several times with boiling water or weak lye, if it be a colza-oil lamp. Schist-oil lamps do not require cleaning inside.

Tin constant-level lamps.

38. The pump-case of the lamp and the outside of the burner will be cleaned every week with whiting moistened with a little oil

When the inside of a lamp or a burner becomes encrusted with oil, it will be cleaned as has just been described.

Moderator lamps.

39. Every week the outside of the lamp will be cleaned with tripoli moistened with spirits of wine, and the little wire-cloth strainer placed under the burner will be removed and cleaned in boiling water.

When a lamp is taken from the apparatus to take the place of a spare lamp, the wick will be removed and the oil poured on the strainer; a turn of the key will be given to the works, and the lamp turned upside down on the dripping-pan.

The outside of the lamp will be polished with tripoli and the burner cleaned.

Cleaning the glass chimneys.

40. When the chimney of a lamp is spotted with burned oil, the spots can be removed by rubbing with a linen cloth dipped in oil; then it should be carefully wiped and polished with whiting. Proceed in the same manner to remove the white polish which forms on the chimneys of lamps burning schist oil, but do not dip the linen cloth in oil.

41. In apparatus of the lower orders showing a fixed light varied by flashes, the revolving machinery should be cared for as follows: Revolving machinery.

Every morning the case, the wheel for communicating the motion, and the wheel of the chariot will be dusted

The large vertical rollers, the small horizontal rollers, and the ways on which they run should be cleaned with the greatest care.

Every week the rollers will be removed, their axes wiped, a little stem of wood wound with a cloth passed into the holes into which they set, and a little clock-oil put in before they are replaced.

Care should be taken to remove but one roller at a time, so that several may always be in place.

From time to time, clock-oil will be put on the axes of the various parts of the works.

Each year, in July, the works will be completely taken apart by the keepers, and cleaned throughout.

To clean the brass parts of the works, tripoli moistened with spirits of wine will be applied to their surfaces, and they will be rubbed with a small silver-plater's brush until they are well polished.

If there be spots of verdigris which cannot be removed with the brush, they can be made to disappear by rubbing them with tripoli and a little spatula of soft wood.

The iron and steel pieces should be simply rubbed with a spatula of soft wood dipped in oil

The pivot-holes and the screw-holes will be cleaned by a little stem of wood wrapped in linen cloth.

Before putting the works together, a little clock-oil will be put in the holes through which the axes pass, and all iron and steel pieces will be rubbed with a piece of cloth greased with tallow.

42. All utensils made of tin used about the light should, twice a year, or oftener if necessary, be polished with whiting moistened with oil. Cleaning the tinware.

## CHAPTER IV.

### NAME AND USE OF THE TOOLS AND UTENSILS EMPLOYED ABOUT SMALL LIGHTS.

43. The colza oil used in lamps intended for small lights should be strained by the keeper.

Strainer. The oil-strainer is in two parts: the upper part is the strainer proper; the lower is a vessel to receive the strained oil.

The strainer proper is a tin plate pierced with holes; on it is placed a piece of cloth and a layer of fine sand from 2 to 3 centimeters in thickness.

Once a month the piece of cloth ought to be washed in warm water and soap, and the sand washed out in boiling water. The sand should not be replaced until perfectly dried. To effect this the sand should be heated in a vessel.

Sea-sand should never be used, even when it is washed in fresh water.

Schist oil need not be strained, and should be used as received at the light-house.

Service-box. 44. The service-box has a transverse handle and a cover with two lids.

It is divided into three compartments:

The first, the smallest, receives a flat tray, on which are temporarily placed the greasy rags and the trimmings from the wicks; under this are placed the clean rags for wiping the glass chimneys.

In the second are placed one or two spare chimneys.

The third should contain the following articles:

Triangular scraper. A *triangular scraper*, for removing burned oil sticking to the edges of the burner.

Bottle-brush. A horse-hair *bottle-brush*, for cleaning the lamp and the air-tube of the interior of the burner.

Curved scissors. A pair of *curved scissors*, for trimming the wicks of the lamps.

Wick-measure. A tin *wick-measure*, curved at the ends, for cutting the wicks to a proper length.

Mandrel or wick-mold. A tin or wooden *mandrel*, conical in form, to facilitate the placing of the wick on the wick-carrier.

Tin dripping-pan. 45. The dripping-pan is a square, flat vessel with a double bottom. The upper one is movable and pierced with holes; the other has a little pipe for drawing off the liquid. It is used for draining the burners, lamps, &c.

Lighting-lamp. 46. The lighting-lamp is used for the double purpose of giving light to the keeper and of furnishing the means for lighting the apparatus.

One of the sides of this lamp is arranged to receive a little hand-lamp, called a *lucerne*.

Lucerne. 47. The lucerne is used to light the wick of the lamp of the apparatus.

It has in the middle a copper screw-button, which is taken off to put in the oil and wick. Near the ring, which serves as a handle, is an air-tube, on which the thumb is placed to prevent the oil from running out when the lucerne is tipped forward.

Oil-can. 48. An oil-can is used to fill the lamp-cistern. It should be placed every evening, full of oil, on the service-table of the light-room, to be used, if necessary, to fill the cistern of the spare lamp.

For schist oil, care must be taken to keep this can tightly closed.

Oil-pump. 49. This pump is used to draw off colza oil from the casks into the butts,* and from the butts into the oil-carrier, that required for several nights' use.

Oil-carrier of tinned copper. 50. Besides the use above mentioned, it is used to transfer the oil from one butt to another when that is necessary.

* Oaken cases, lined with tin, have now been substituted for the butts.

51 The form of the lamp-stand varies according to the lamp it is intended for. Each apparatus has two; one should always remain on the table of the light-room, the other in the store-room. Foot of the lamp, called the lamp-stand.

52. The rouge-box is double, one part being inclosed in the other; the inner one contains the rouge, either in lump or in powder. Above this inner box is the chamois skin, used solely for rubbing the rouge from the apparatus or lantern-glass. Rouge-box.

53. The tripoli should be shut in a box, and be used only for cleaning the copper utensils. Tripoli.

54. A sash-brush is ordinarily used to spread the polishing-rouge on the glass surfaces to be cleaned. Sash-brush.

55. The hand or crumb-brush is half-round in form, and has a handle from 30 to 40 centimeters long; it should be used to sweep off the pedestal, the interior walls of the lantern, the landing and the last four or five steps of the stairs. The ordinary broom might occasion accidents on this part of the structure by reason of its long handle. Hand-brush.

56. The silver-plater's brush is used to rub the copper pieces on which tripoli has been spread. It is particularly intended for the copper parts of the clock-work. Silver-plater's brush.

57. The feather-duster is used to dust the illuminating apparatus, the lantern-glass, the chariot and the clock-work case. Feather-duster.

58. The glazier's pincers may be required when a lantern-pane is to be replaced. To slightly reduce the size of a pane, place the pincers so that the claws may seize the edge and yet make a very acute angle with it; by bearing a little on the handles of the pincers and turning the hand outward, small particles of glass will splinter off. This should be done very slowly, with great care, removing but a little glass at a time, as prescribed in Article 31. Glazier's pincers.

59. The screw-drivers and wrenches are used in taking apart and putting together the revolving machinery. After being used, they will be rubbed with a cloth greased with tallow or lard, and kept free from dampness. Screw-drivers, wrenches and hammers.

60. The circular scraper is formed of an iron stem, which carries at one end an arc of a circle, with which to scrape the outside of the wick-carrier, and at the other end a little disk, to scrape the inside. Utensils peculiar to the lamps of sideral apparatus: circular scraper.

61. The dripper for the burner is a little tin vessel with a turned-up edge. It is so shaped that it can be placed on the nappe of the apparatus. Dripper for the burner.

It is put in place every time the wick-carrier is changed.

Presented for the approval of his Excellency the Minister of Agriculture, Commerce and Public Works, by the Inspector General of Bridges and Roads, Director of the Light and Buoy Service.

Paris, May 3d, 1860.

L. REYNAUD.

EXAMINED AND APPROVED:

Paris, May 10, 1860.

*The Minister of Agriculture, Commerce and Public Works.*

For the Minister, and by authority,

*The Counsellor of State, Director General of Bridges, Roads and Railroads,*

E. DE FRANQUEVILLE.

IX.

# INSTRUCTIONS

FOR THE

# SERVICE OF FLOATING LIGHTS.

## CHAPTER I.

### PERSONNEL.

1. The personal equipment for a floating light consists of a captain, a mate, a boatswain, and sailors who are also lamp-lighters; the number of the latter is fixed by ministerial decision. They are placed under the orders of the engineers and the deputy assistant engineers.

2. They can only be appointed to this service as sailors after having had at least three years' service on board of a French naval vessel, and knowing how to read and write.

3. The numbers and pay are fixed by the Minister. **Nominations.**
The nominations are made by the prefect, on the recommendation of the engineer-in-chief.

Three per centum of the pay which is withheld is placed to the credit of the fund for the support of invalid sailors.

4. The captain is responsible for the service on board his vessel, and exercises over the crew all the powers that belong to captains in the merchant service.

He is charged with the keeping of all records and with the correspondence.

His place is supplied by the mate during his absence.

5. The boatswain looks to the execution of the orders of the captain, and is especially charged with the maintenance of order and cleanliness in the sailors' quarters. He may be excused from the manual labor relative to cleaning the ship: but he is expected to direct this work in all its details, and to stand his watch the same as the other sailors, except in special cases, of which the engineers will be the judges. **Boatswain.**

In case of absence his place is filled by a sailor designated for this duty by the captain.

6 The ship-carpenter may be excused by the engineers from all participation in the work performed by the rest of the ship's company. He is required to execute all works of repair, &c., relating to his trade, that are prescribed by the captain. **Ship-carpenter.**

7. The captain and mate have alternately two weeks of duty and two weeks leave of absence; the sailors pass alternately one month on board ship and two weeks on shore. **Leaves of absence.**

The lengths of time for duty on board ship and leaves of absence may be modified by the engineers, according to circumstances, the proportions remaining the same. The duration of leaves of absence during the bad season, that is to say from the 15th of October till the 15th of March, is reduced one-half at some stations, by special decisions.

The number present on board, should consequently be at all times a captain or mate and two-thirds of the balance of the ship's company.

The captain may besides suspend or reduce leaves of absence when, in his judgment, the good of the service requires it.

No one is allowed to leave the vessel until the return of his relief. When one or several men are not on hand to resume their duties on the expiration of their leave of absence, the captain keeps on board one or more of the sailors whose turn it may be to go on shore that day, and reports the fact to the engineer. He takes the necessary steps, to grant to the men who have been retained on board, the leave that it became his duty to deprive them of for the time being.

When the boat used for going to and returning from shore cannot make the trip at the time fixed for her departure or return, the time of the men about to go ashore will be reduced in consequence; however, if the delay of time be of such length that the sojourn ashore will be limited to less than six days, the trip included, the leave of absence will be extended the same length of time, that is to say, up to the end of the next term.

Every man who, without good excuse therefor, does not return on board at the expiration of his leave loses six days' pay for the first failure, and for the second and succeeding ones double that amount. A reduction equivalent at least to the time passed on shore without leave is made on his next succeeding leave.

**Duties while on leave.**

8. The officers and sailors are subject to the orders of the engineer while they are ashore, and cannot leave the place of their residence without authority. They are required to obey orders for duty that may be given them, whether it be to return on board ship, or to perform labor relative to transporting materials to light-houses or beacons in the department.

**Rations.**

9. Special rules, established by the engineers and the Director of Lights, determine what is to be allowed relative to provisions. The captain is responsible for the rations used on board, and he renders an account of them. He may put one of the sailors in charge of the kitchen, or require this duty to be performed by each man by turns; but he is not to be excused from any duty relative to the service of the light or the care of the vessel

**Uniform.**

10. The uniform of the persons on board of light-vessels is as follows:

1st. For captains:

Coat of blue cloth with turn-down collar, ornamented on each side with a gold embroidered star, and for facings a double cord of gold braid with fringe 0.006 of a meter wide.

Cap of blue cloth with the same fringe around the band, connected in front with an anchor surmounted by a star embroidered in gold. On occasions of public ceremony the cap is replaced by a French chapeau with plain lace. Vest and pantaloons of blue cloth in winter and white linen in summer.

Gilt buttons for coat and vest, stamped with a star, and bearing in relief the words "Phares et Balises." Sword and hilt black and without gilt.

In the daily duty on board ship, the coat is replaced by a straight-collar round jacket with uniform buttons, and the cap by one without ornaments.

2d. For mates:

The same uniform as that of the captain, but without the fringe on the facings and the cap, also without the French chapeau and without the sword.

3d. For boatswains and sailors:

Sailor's jacket of blue cloth with turn-down collar, ornamented on each side with a star worked with yellow worsted. Boatswains wear yellow worsted lace on the sleeves

Pantaloons and vest of blue cloth in winter and white linen in summer. Buttons the same as those of the officers, but not gilt. Shirt of white linen with turn-down collar and blue cuffs; a knit cravat of blue worsted.

Sailor's hat of waxed leather, with an anchor surmounted by a star and the name of the boat; the letters and ornaments painted white.

The ordinary dress on board ship is composed of an overshirt (*vareuse*) of unbleached linen reaching to the thighs, of a red woolen shirt, of a knit cotton shirt striped alternately white and blue, of linen or cloth pantaloons, and a beret of blue wool with a black leather strap, with a topknot of yellow and blue threads, and two bands of yellow worsted 0 015 of a meter wide for boatswains and a single one for sailors.

## CHAPTER II.

### MANAGEMENT OF THE LIGHTS.

11. Every day, about an hour before sunset, the cisterns of the lamps will be filled, and note taken of the weight of the oil used for this purpose; then the lamps and their reflectors will be mounted and set in the lantern. **Evening duties.**

Immediately at sunset, the sailor on duty, provided with a lighted lucerne, will enter the little house in which the apparatus is kept and light the lamps, following the directions prescribed in the "Instructions for the service of small lights." He will then wipe the lantern-glass, and test the ventilators, which he will open more or less, according to the state of the weather. The lantern will be hoisted at nightfall. In lights with eclipses, the motor-weight of the revolving machinery will be wound up at the same time. The alarm-bell (carrillon) connected with the machine to give notice that the weights have nearly run down, will also be wound up.

12. The light will be watched the entire night by the sailors, who take watch by turns

When the sailor on watch perceives that one of the lights has gone out, or has lost a considerable part of its brilliancy, he will call the boatswain, who will lower the lantern and correct the evil.

13. The lantern will be lowered to the deck every four hours in order that the lamps may be trimmed. When any accident necessitates the lowering of it less than two hours before the regular times for trimming, advantage will be taken of this circumstance to trim all the wicks, and the operation will only be renewed at the expiration of the following period of four hours.

These operations ought to be executed with the greatest possible rapidity, and the trimming will be done by working at least two men at a time.

While this work is going on the lantern will be replaced by a common hand-lantern, which will be hoisted to the proper height; it will only be taken down when the regular lantern has been replaced.

14. Immediately at break of day the lantern will be lowered to the lantern-house, the lights will be extinguished, the motor-weight of the revolving machinery of lights with eclipses will be lowered to the bottom of the well, and the morning duties will be commenced. **Morning duties.**

The lamps and reflectors will be taken down to the store-room, the lamps will be emptied, and the weight of the oil taken from them noted; they will then be cleaned, as will also the reflectors, conforming to the instructions; the wicks will then be cut or new ones substituted.

The lantern will then be cleaned, and also the glass, both on the inside and outside; and after having wiped the windlass, it will be covered with its hood.

15. The lantern will be raised or lowered only on the order and in the presence of the captain, the mate or the boatswain, and it will be done in the following manner: **Raising and lowering of the lantern.**

For raising it, two men will seize the cranks of the windlass and two others the relief-tackle. They will work together, and the latter two will be careful to take a turn on the iron cleat designed for this purpose, in order to hold the lantern in case the hoisting-chain should break.

To take the lantern down, the work is done in the same manner, but the process is just the reverse. The men working the relief-tackle will pay it out gradually, while the weight of the lantern is on it, and will take a double turn on the cleat when the vessel rolls much.

16. In bad weather, when the rolling of the ship is so heavy that there is danger of the lights being put out, or prevents the full power being given to the flame, the captain may order the lantern to be raised only one-half its usual height, and will note this fact in the light-journal.

Care of the apparatus.

17. The keepers will conform strictly in all that relates to the service, and to the care of the lamps, reflectors, revolving machinery, lantern, &c., and to the rules laid down in the "Instructions for the service of small lights."

The axis of the drum of the windlass and those of the pulleys used to hoist the lantern will be greased as often as may be necessary to render their motion easy.

Fog-signals.

18. In foggy or thick weather, during the night or day, the fog-bell will be tolled. The tolling will last one minute, and will be repeated every three minutes. When a vessel passes near the light-ship, the bell will be tolled continuously.

Every time the bell is put in operation the fact will be noted on the log, together with the day and hour when it commenced and ceased.

## CHAPTER III.

### DUTIES ON BOARD SHIP.

19 The vessel will be kept in the same order and state of cleanliness that is required on board of French men-of-war. Every morning the vessel will be washed and swept both on deck and below. The floor below deck will be swept after each meal. The deck, the floor below and the store-rooms will be rubbed with bath-brick every month. The vesse. will be thoroughly washed outside every week. During the summer, the deck will be sprinkled twice a day. **The vessel.**

The outside of the vessel, which is painted in oil, will receive a new coat of paint four times a year; the interior will receive only one coat during the same period.

The lantern-masts will be greased with tallow twice a month; before being applied, they will have the old grease scraped off with a wooden scraper.

In summer, when the weather is very warm, the deck of the vessel will be protected during the day from the sun's rays by an awning.

20. Twice a week, when the weather will permit, the articles of bedding, such as mattresses, pillows and bed-clothing, will be brought up on deck to be beaten and aired for at least two hours. This operation should be completed by 9 o'clock in the morning in summer and by 11 o'clock in winter. **Articles of bedding.**

21 The pumps will be worked every morning and evening. If there be no water in the hold, some will be poured in at least once a week to render the vessel healthy. In case the pumps show more water in the hold than usual, the captain will be immediately notified of the fact. **Pumps, ballast and hold.**

The ballast should be cleaned every six months.

During the warm weather the hold will be frequently ventilated by means of a wind-sail.

22. The captain will take advantage of good weather, especially during low spring tides, to examine the mooring and bridle-chains as far down as possible, without raising the anchors. He will examine particularly the condition of the shackle and swivel on the bridle-chain. He will grease the latter, if it does not turn round freely, and will immediately replace it by another, if it be sufficiently worn to cause apprehensions of danger. **Chains.**

23. The captain will take the greatest precaution to guard against danger of fire, and will see that each fire-pump is in good working order at all times. To test this he will cause it to be worked every day of the week. **Fires.**

Only two fires will be allowed on board—one in the kitchen, the other in the officers' cabin.

24. In ordinary weather there will only be one man on watch on deck; in bad weather, the captain will place two or more on watch, and will assure himself of their vigilance by frequent inspections. **Men on watch.**

The keeper on watch will sound the hours and half hours on the ship's bell.

25. When swinging the ship at her anchor all the crew will come on deck to assist in this manœuver. They will do the same when the chain is to be paid out or taken in. **Swinging.**

26. When it is known that a storm is coming on, either by the low fall of the barometer or by any other indication, the captain will pay out chain, taking care to use the clutch frequently, and will immediately take all other proper measures to be in readiness for the storm. **Storms.**

He will assure himself at short intervals, by examining day-marks, if the vessel holds her position, and will have recourse to soundings, if the day-marks be masked by fog or hidden by the darkness of night.

After the weather clears up, he will take in the chain that was paid out, and the length of the hanging chain will be reduced as much as local circumstances will allow.

The vessel parting her moorings.

27. When the vessel breaks from her moorings the captain will immediately let go the spare anchor, and endeavor to mark that position. If this position differs but little from the one the light-ship should occupy when properly moored, and the change will cause no danger to other vessels, he will hold on there until he can recover his proper place, and the light will be kept up as usual. If, on the contrary, the change in position might mislead others, or if there be any doubt in this respect, the captain will have the lantern lowered if the accident occurs at night, and the balls on the mast if it takes place during the day.

He will have to decide whether it be better to keep at sea or seek a harbor. The regular ship's lights will then be displayed at night.

Ship's boat.

28. The captain will positively forbid any of the crew to make use of the ship's boat for fishing or for going ashore. He can only plead in justification of a departure from this rule some great urgency, and will do it then only on his own responsibility. He will mention the fact, and his reasons therefor, on the log.

Call-signal.

29. The call-flag or signal will be hoisted whenever one of the crew is so sick as to require medical attendance.

One or two men on leave of absence, complying with the orders of the engineer, will come off in the boat used for going to and from shore, in answer to the signal.

Neighboring vessels.

30. The captain will not allow any vessel to lay sufficiently near the light-ship to mask the light in a direction that would be injurious to safe navigation. If his warning be not obeyed, he will prepare a *procès-verbal*, which he will transmit to the engineer.

Aid to shipwreck'd people.

31. The captain will use every effort in his power to give assistance to vessels in distress, without compromising the lives of his own men. He will receive shipwrecked people on board, and will give them every attention that their unfortunate condition claims. He will immediately hoist the call-signal.

Any fact relative to such disasters will be reported in the log.

Life-preservers and other apparatus of that kind will receive the greatest care, and will be disposed in places where they can be easily reached.

Visitors.

32. No visitors will be received on board until after the morning duties have been completed, and then only till an hour before sunset. No more than four will be allowed to come on board at one time; they will be forbidden to bring provisions of any kind whatever; and will be required to write their names in the register kept for this purpose. Save in case of shipwrecked people, no one unconnected with the service will be allowed to sleep on board.

## CHAPTER IV.

### RECORDS.

33. The captain will keep the following books and records:

1st. *Light journal.*—In this will be written every day the hour when the lights are exhibited, the trimming and times of extinguishing, any accident that happens to the apparatus at night, the consumption of oil, the reception of supplies relative to the illumination, &c.

2d. *Monthly reports of supplies.*—These reports will be made in triplicate, two of which will be forwarded to the engineer at the commencement of each month. They will give a statement of the amount consumed the past month, and the amount of supplies relative to the service of the light on hand.

3d. *Monthly reports of the consumption of oil.*—Two of them will be forwarded to the engineer.

4th. *Ship's log.*—In this will be noted, every hour, the direction and force of the wind, the direction and velocity of the current, the trim of the vessel, the state of the sea and the atmosphere, the height of the barometer and the exterior temperature. There will be noted every day, in the column of Remarks, the work done on board, changes in the personnel, accidents, &c.

5th. *Provision report.*—This report will give a daily account of the provisions received and consumed.

6th. *The condition of the lights in sight.*

7th. *Register of visitors*

8th. *Inventory of the light-station.*

34. The sailor on watch writes in a note-book, all the events relative to the light or the ship that take place during the time he is on watch, and which form a part of those that the captain is required to note in the journals. He takes note, with as much accuracy as possible, of the number and kind of vessels that pass in sight of the station.

Proposed for the approval of his Excellency M. the Minister of Agriculture, of Commerce and of Public Works, by the Inspector General of Bridges and Roads, (des Ponts et Chaussées,) Director of the Light and Buoy Service.

Paris, May 27, 1864.

L. REYNAUD.

EXAMINED AND APPROVED:

Paris, June 13, 1864.

*The Minister of Agriculture, of Commerce and of Public Works.*

For the Minister, and by authority,

*The Councillor of State, Director General of Roads, Bridges and Railroads,*

E. DE FRANQUEVILLE.

X.

# REGULATIONS

FOR THE

# KEEPERS OF LIGHTS ON THE COASTS OF FRANCE.

---

1. The light-houses and small lights are under charge of agents, called light-masters (*maîtres de phare*) and light-keepers.

These persons are placed under the orders of the Engineers and Assistant Engineers of Roads and Bridges.

2. They are appointed by the prefect of the Department, on the nomination of the engineer-in-chief. Nomination of keepers.

3. In the selection preference is given to old soldiers of the Army and sailors of the Navy.

4. To be appointed light-master or light-keeper, it is necessary:

1st. That the person be a Frenchman, at least twenty-one, and not more than fifty years of age.

2d. He must be free from any infirmity that would interfere with active daily exercise.

3d. He must hold a certificate of good character.

4th. He must know how to read and write, and possess a knowledge of the elementary principles of arithmetic.

5. The annual salary of light-masters is fixed at 1 000 francs. Salaries.

The light-keepers are divided into six classes, the annual salary of each being as follows:

| | Francs. |
|---|---|
| 1st class - - - - - - - - - - | 850 |
| 2d class - - - - - - - - - - | 775 |
| 3d class - - - - - - - - - - | 700 |
| 4th class - - - - - - - - - - | 625 |
| 5th class - - - - - - - - - - | 550 |
| 6th class - - - - - - - - - - | 475 |

Each light-master or light-keeper is allowed a certain quantity of coal or wood for fuel.

Light-masters and light-keepers of isolated stations out at sea receive an allowance for provisions, which is fixed by the administration according to the circumstances of the case.

The salaries and allowances are paid regularly every month. The fuel is furnished in kind, once or several times a year, as the engineers determine.

6. The salaries of light-masters and light-keepers are subject to a stoppage of five per cent., and these persons enjoy the privilege of retiring-pensions, conformably to the law of June 9, 1853. Pension-fund.

7. The light-masters and keepers are sworn in immediately after their appointments, in order to be qualified to prepare a valid *procès-verbal*, in case an infraction of the rules is committed at the station to which they are attached

Number of keepers.

8. The number and classes of keepers attached to each light-house are determined by ministerial decisions, upon the recommendation of the engineer-in-chief and the advice of the prefect and the Inspector General, Director of Lights.

This number is never less than three for light-houses of the first order, and two for those of the second and third orders.

Light-masters.

9. Light-masters are charged with a general supervision of the service of several light-houses or small lights. This title may be given also to principal keepers who have merited it by distinguished services.

Principal keepers.

10. In light-houses where there are several keepers, and where there is no light-master, one of the keepers is called chief or principal. In case of absence, his duties devolve on the first assistant.

Duties of light-masters and principal keepers.

11. Light-masters and principal keepers are responsible for the general state of the stations under their charge, and for the reception of the oil. They are especially charged with the keeping of the records and attending to the correspondence

The other keepers (assistants) owe obedience to them in every thing relating to the service, reserving the right of appeal to the engineer.

The principal keepers are required to perform their share of duty with the others in attending the lights and keeping the apparatus in order; no distinction being made in this respect.

Light-masters are exempted from this service; but they are required to visit the light at least twice every night, and they may be obliged temporarily to perform the duties of principal keeper, by order of the engineer-in-chief of the department, in cases when exceptional circumstances render this measure necessary.

Duties of light-keepers.

12. The keepers are jointly charged with the attendance of the light, and the preservation as well as the cleanliness of the illuminating apparatus, utensils, furniture and the buildings. They are required to conform strictly to the rules and directions for the service, given them by the engineers, and to exercise continually the most careful supervision over everything about the establishment committed to their care.

At light-houses of the first three orders the keepers are required to keep watch of the apparatus during the entire night. For this purpose they take watch by turns.

The keepers of small lights (*fanaux*) are required to visit them at least once in the middle of the night during summer, twice at equal intervals during the nights of winter, and more frequently when, from any reason, it is feared that the intensity of the flame may be diminished, or is in danger of being extinguished.

Morning duties.

13. At daylight the keepers should extinguish the light and immediately prepare for lighting up the next night; the duties of cleaning up will then be performed conforming to the rules and special instructions, so that all the duties of the morning may be completely finished two hours after sunrise.

Evening and night duties.

14. One hour before sunset all the keepers should be at their posts, in order that the evening duties may be undertaken in accordance with instructions.

The lighting up of apparatus, the lamps of which have multiple wicks, should be commenced a quarter of an hour after sunset, so that the flame may be at its full height by dark.

The keepers are required to remain in the light-house during the entire night, and there ought always to be at least one in the service-room, to come in case of necessity to the assistance of the one on watch.

All the keepers are required to come immediately on the call of the keeper on watch, should anything whatever require their presence.

The keeper on watch writes in a note-book his observations upon the various matters relating to the service of the apparatus, the appearance of lights in sight, the state of the atmosphere, vessels in sight, &c. The principal keeper transcribes the next day, to the register kept for the purpose, such of these notes as he thinks should be brought to the attention of the engineer.

If a light goes out or burns dimly during the night, the fact should be noted on the register, stating the cause and the hour of the night when it occurred.

Day duties.

15. During the day the keepers ought never, under any circumstances whatever, to be absent all at one time. To this end they take turns of duty successively, either by the day or week, according to the orders of the engineer.

Care and cleanliness.

16. Special instructions regulate the duties of keepers in regard to the care of the illuminating apparatus and lantern. For the cleanliness of the establishment they are required—

1st. To brush and wipe every day the table and the service-gallery as well as the lantern-room.

2d. To brush and dust every day the store-room, and all the rooms and stairways of the building.

3d. To wash once a week the stairs and tile or flag floors.

4th. To clean and rub down the floors and brick pavements made in color.

5th. To oil as often as may be necessary the hinges, latches, locks, casement fastenings, &c., made of iron, so as to make them work easily and prevent oxidation.

Visitors.

17. Keepers are forbidden to allow any strange persons to visit the light during the night. They can only admit visitors after the morning duties are finished, and until one hour before sunset. They must always accompany them, must not allow them to go into the illuminating apparatus, nor take more than two persons at a time into the lantern-room.

They are responsible for any and all damage done by visitors.

They will invite all persons who wish to visit the light to first write their names and addresses in a book kept for that purpose, and will admit none who are not willing to accede to this request.

Assistance to wreck'd persons.

18. Light-keepers are required to lend every assistance in their power to navigators who may be wrecked, and to offer them a place to stay in case of need; but they are to give strict attention to the light at the same time, and not endanger its continuance.

They should be on the lookout to save persons cast away near the light-house, and give notice of disasters to the maritime authorities.

Leave of absence.

19. No keeper is to absent himself from his station without the written authority of the engineer, nor without previously having arranged to furnish a substitute. The keepers of light-houses isolated in the sea, to whom leaves of absence are allowed at regular periods, are an exception to this rule.

Rewards.

20. Each year, upon the recommendation of the engineer-in-chief, there may be granted by the prefect, to the most meritorious keepers, a reward not exceeding one month's pay.

The number of keepers to whom this reward is granted must not exceed one-fifth of the total number of all in the department.

In a department where there are less than five keepers, it can only be allowed to one of them.

The Minister decides when these limits may be exceeded in exceptional cases.

Punishments.

21. In case of negligence in the service, or when acts are committed that deserve punishment, the penalties are: first, retention of a part of salary; second, the revocation of appointment.

These punishments are awarded by the prefect, on the report of the engineer-in-chief.

If the circumstances seem to require it, a keeper may be discharged by the engineer or the assistant engineer charged with the supervision of the light, who would necessarily provide a temporary substitute; but his act will not be final until it has been approved by the prefect.

Livret.

22. Each light-master or keeper will keep a livret, in which the assistant engineer writes the rewards given and the punishments inflicted.

Uniform.

23. The uniform of light-masters and light-keepers is as follows:

1st. For light masters—

Coat of blue cloth, turn-down collar, ornamented on each side with a star embroidered in gold.

Cap of blue cloth, with an anchor surmounted by a gold-embroidered star.

Vest of blue cloth in winter and a white vest for summer.

For the vest and coat, gilt buttons, having on them the words *light-master*, (*maître de phare.*)

Pantaloons for winter, blue cloth; for summer, brown Holland.

2d. For principal keepers and assistants of all classes—

Sailor's jacket of blue cloth, with turn-down collar, ornamented on each side with a star embroidered in silk for principal keepers, and in wool for assistants.

Pantaloons and vest same as above.

Brass buttons for vest and jacket, having the words *light-keeper* (*gardien de phare*) on them.

A sailor's hat of waxed leather, with an anchor surmounted by a star, and the words *principal light-keeper* (*chef gardien de phare*) or *assistant light-keeper* (*gardien de phare*) painted white.

24. The service of lights of secondary importance may be confided to persons who are neither classed as light-masters nor light-keepers.

Submitted for the approval of his Excellency the Minister of Agriculture, of Commerce and of Public Works, by the Inspector General of Bridges and Roads, (des Ponts et Chaussées,) Director of the Light and Buoy Service.

Paris, May 3d, 1860.

L. REYNAUD.

EXAMINED AND APPROVED:

Paris, May 10th, 1860.

*The Minister of Agriculture, of Commerce and of Public Works.*

For the Minister, and by authority of

*The Councillor of State, Director General of Bridges and Roads and of Railroads,*

E. DE FRANQUEVILLE.

○

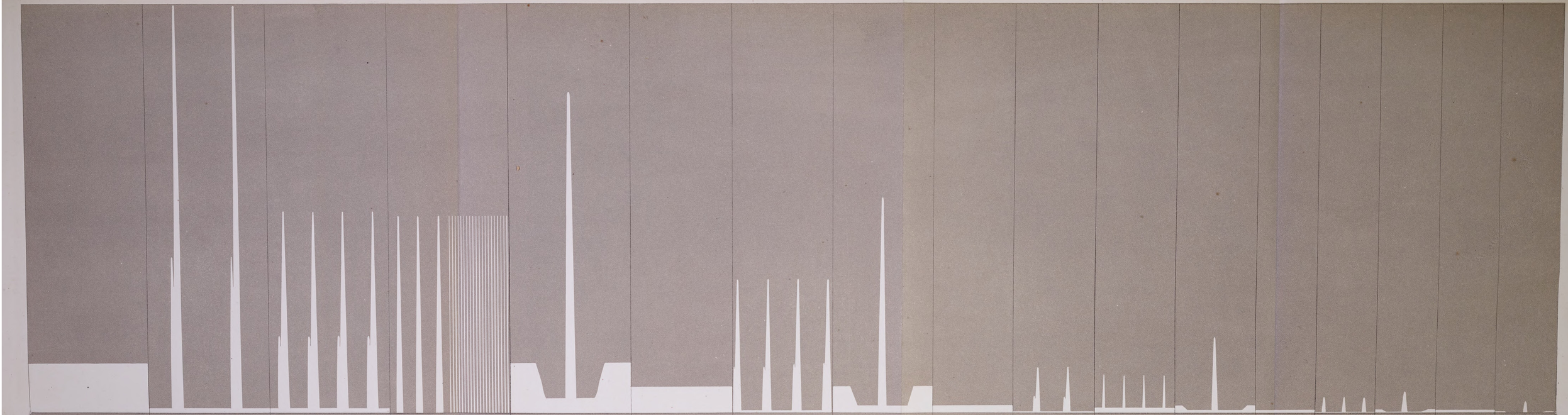


Fig. 1. Fixed light.

Fig. 2. Light with eclipses every minute.

Fig. 3. Light with eclipses every 30 seconds.

Fig. 4. Light with eclipses every 20 and every 3 seconds.

Fig. 5. Fixed light varied by flashes every 4 minutes.

Fig. 6. Fixed light

Fig. 7. Light with eclipses every 30 seconds.

Fig. 8. Fixed light varied by flashes every 3 minutes.

Fig. 9. Fixed light.

Fig. 10. Light with eclipses every 30 seconds.

Fig. 11. Fixed light varied by flashes, but without eclipses.

Fig. 12. Fixed light varied by flashes every 3 minutes.

Fig. 13. Fixed light.

Fig. 14. Light with eclipses every 20 seconds.

Fig. 15. Fixed light varied by flashes every 2 minutes.

Fig. 16. Fixed light.

Fig. 17. Fixed light varied by flashes every 2 minutes.

1st order. D = 1, 84 meters.

2nd order. D = 1, 40 meters.

3rd order. D=1, 00 meter.

3rd order. (Small model) D=0, 50 meters.

4th order. D = 0, 375 meters.

# INTENSITIES AND LUMINOUS RANGES.

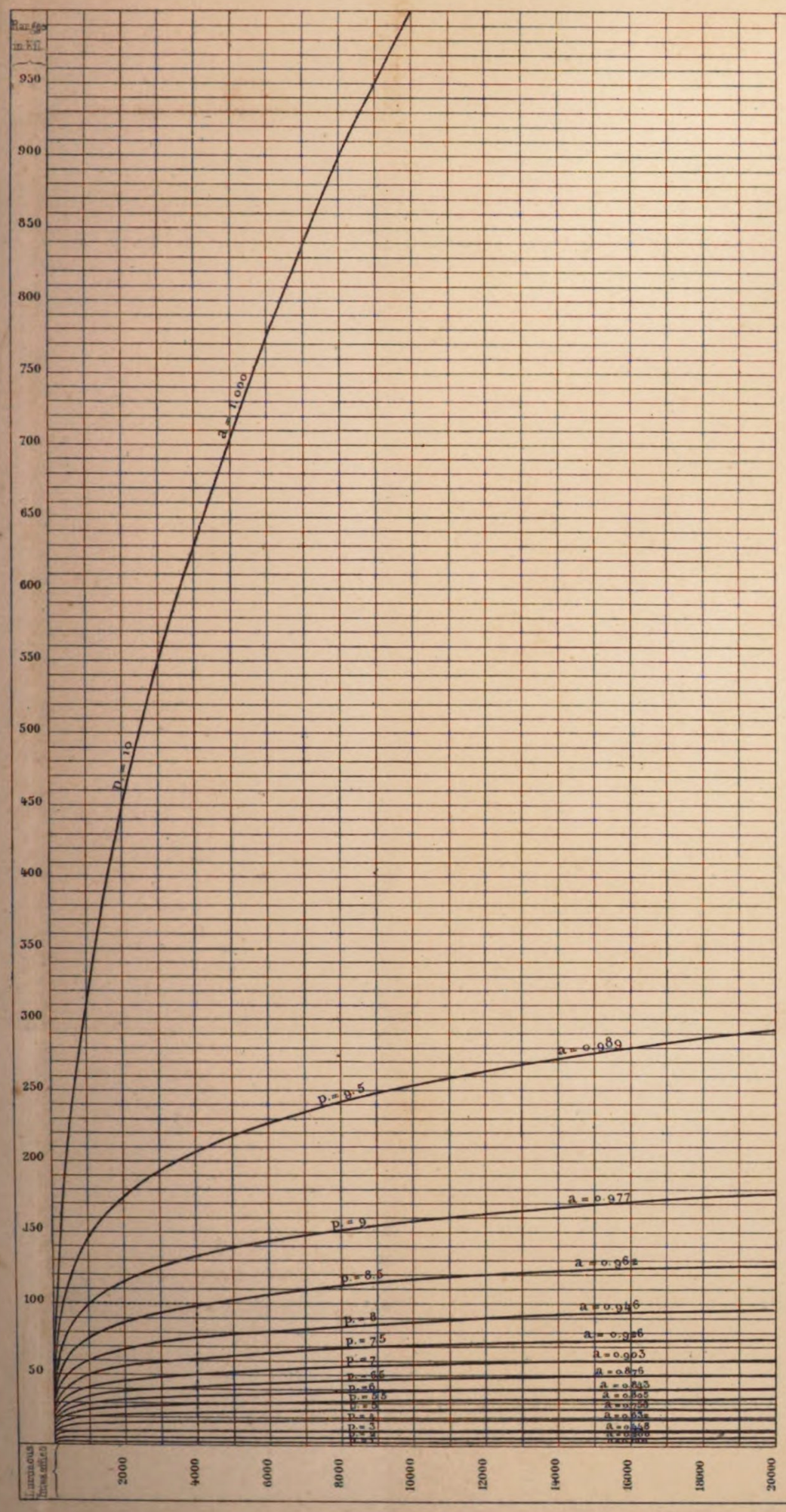



Fig. 1.

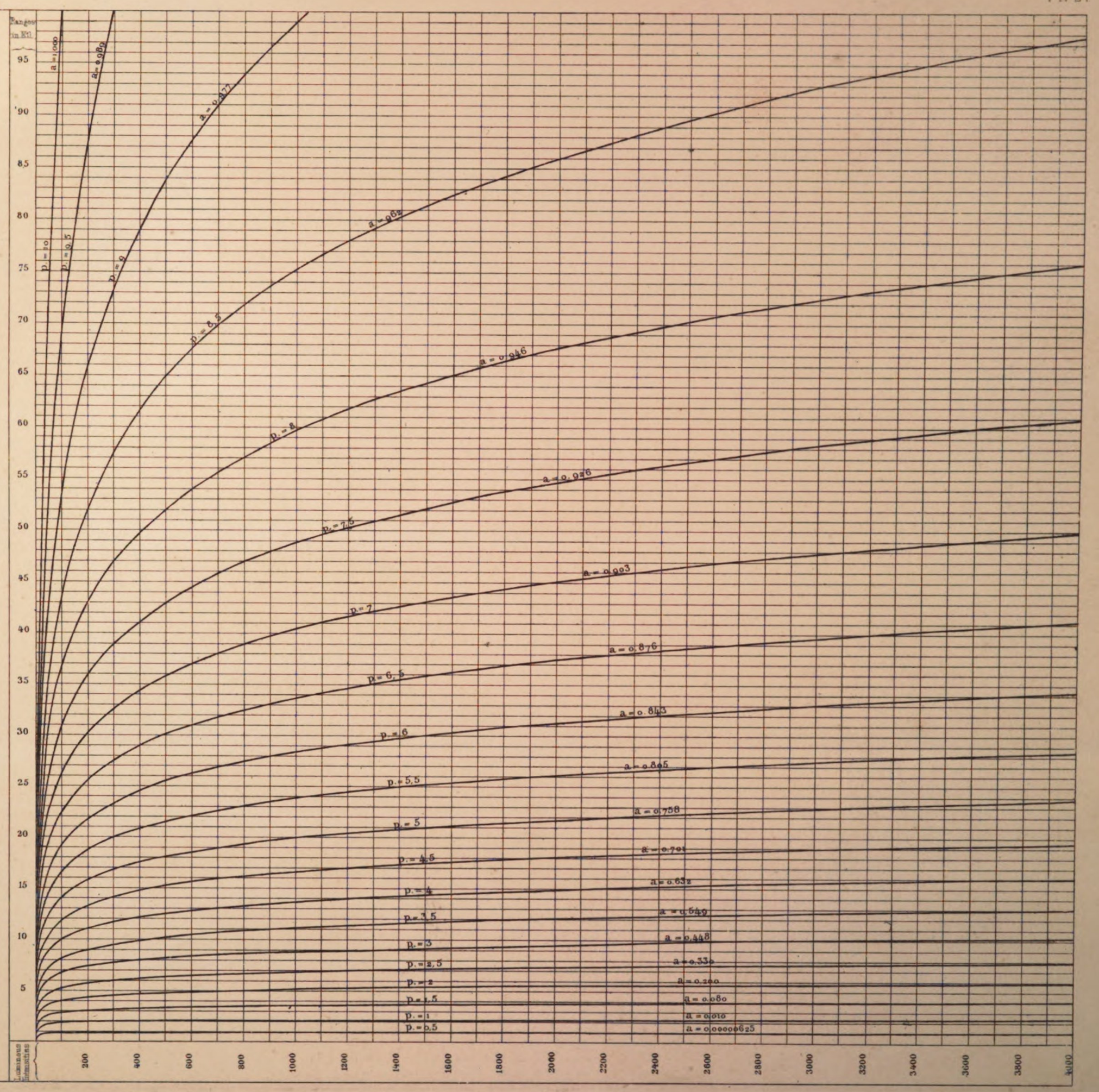



Fig. 2.

# CURVES OF LUMINOUS RANGES.

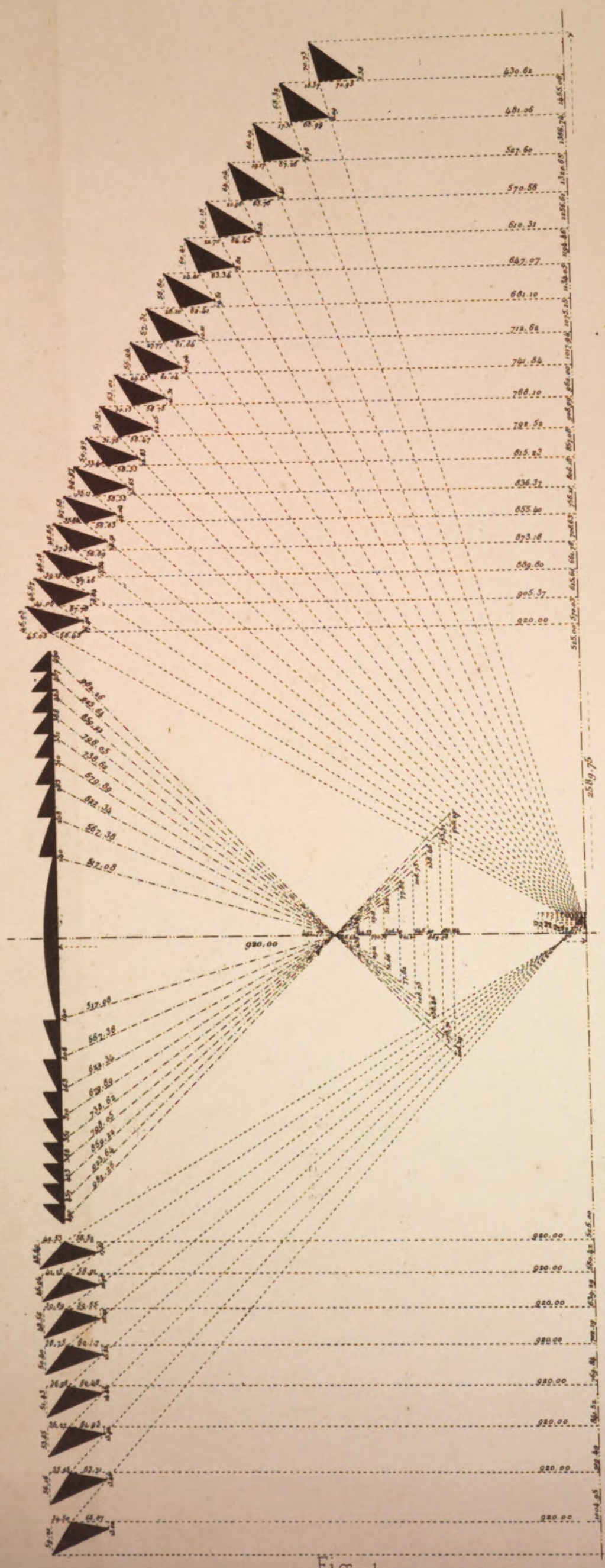



Fig. 1.

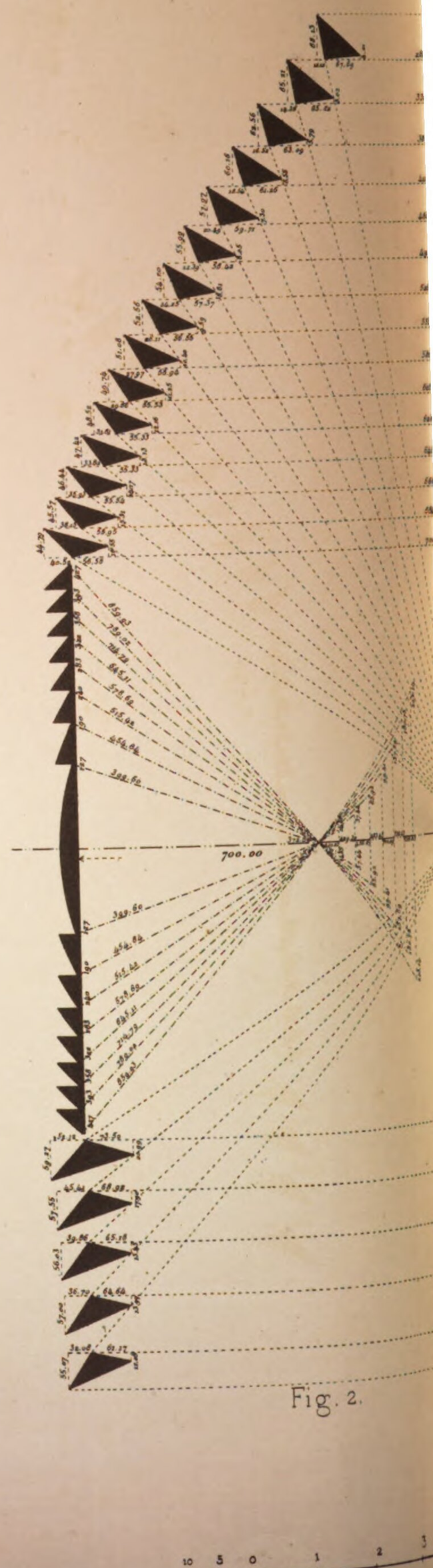



Fig. 2.

PROFILE

PROFILES OF LENTICULAR APPARATUS.

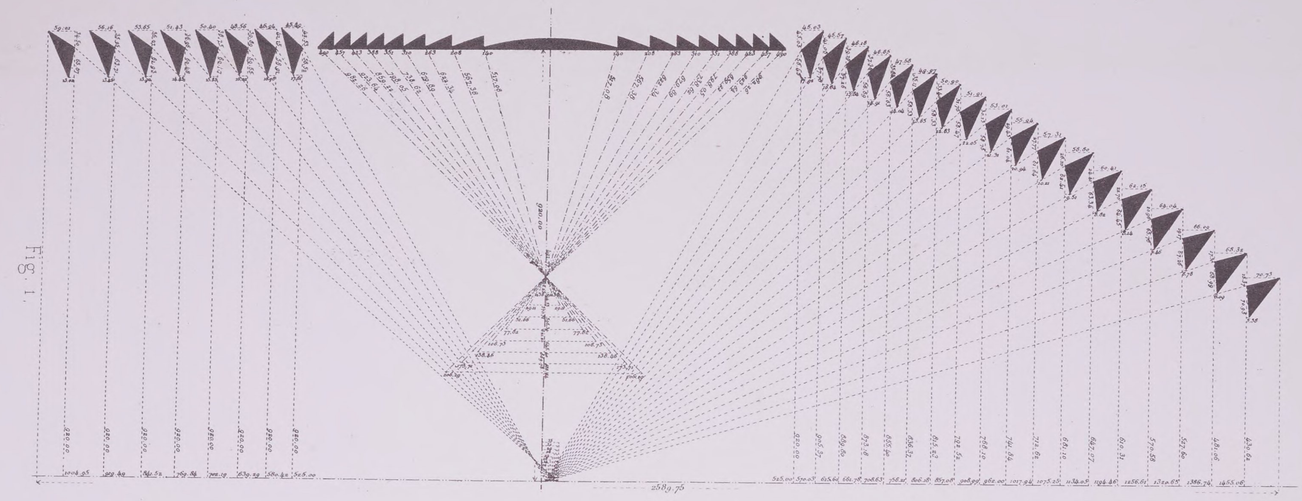


Fig. 1.

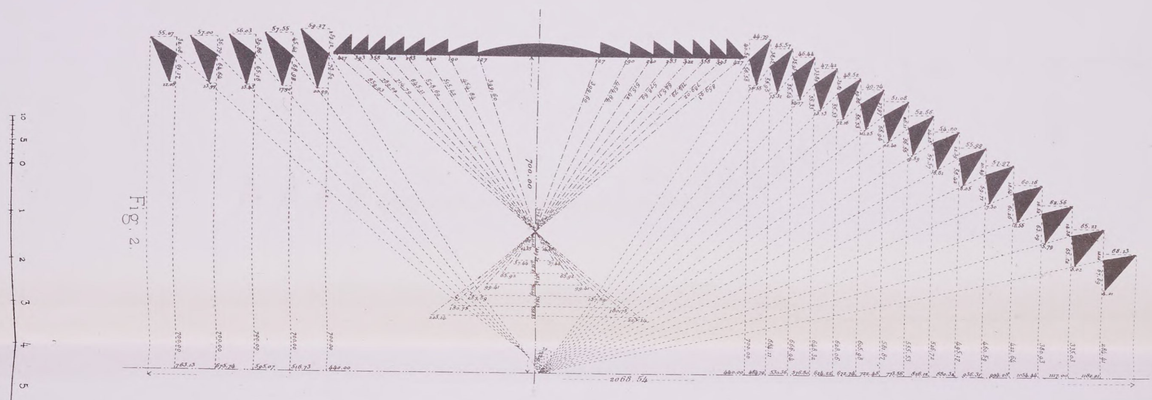


Fig. 2.

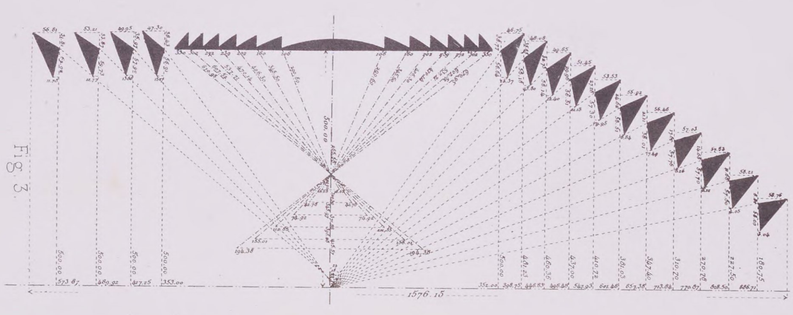


Fig. 3.

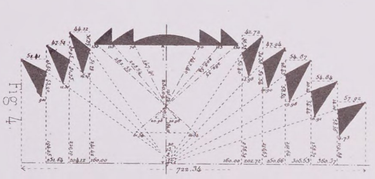


Fig. 4

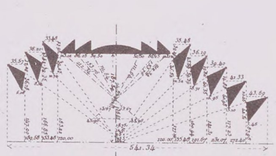


Fig. 5



Fig. 6



Fig. 7

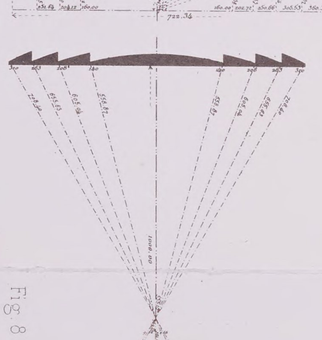


Fig. 8

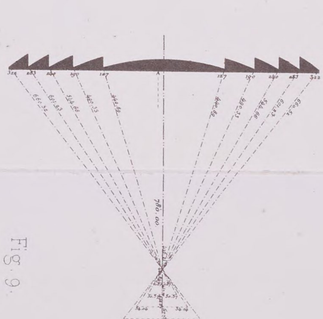


Fig. 9.

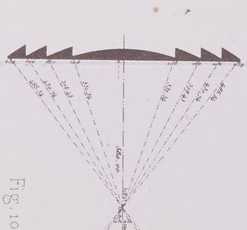


Fig. 10.

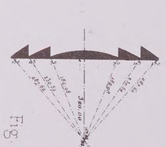


Fig. 11.

Pl. 3.



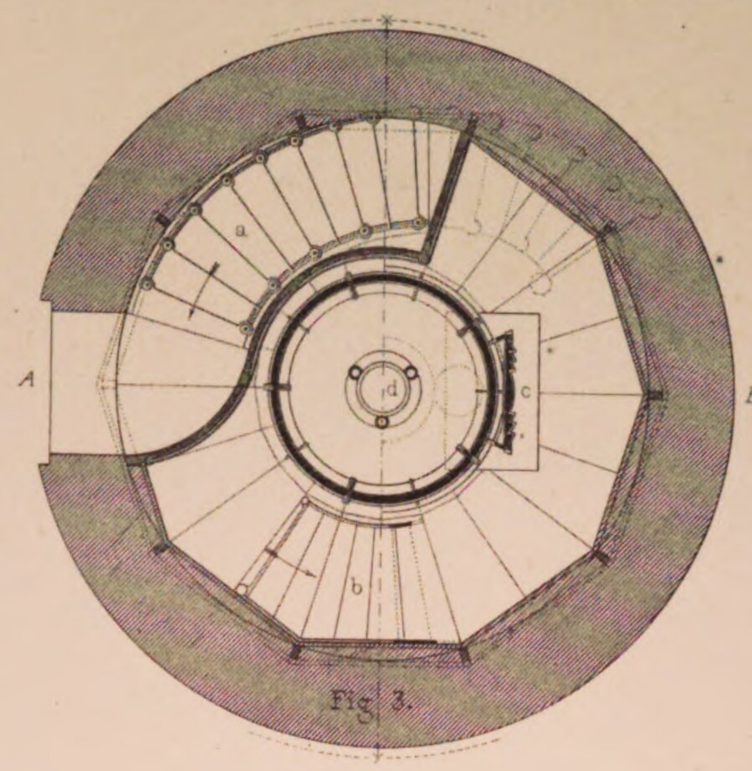



Fig. 3.

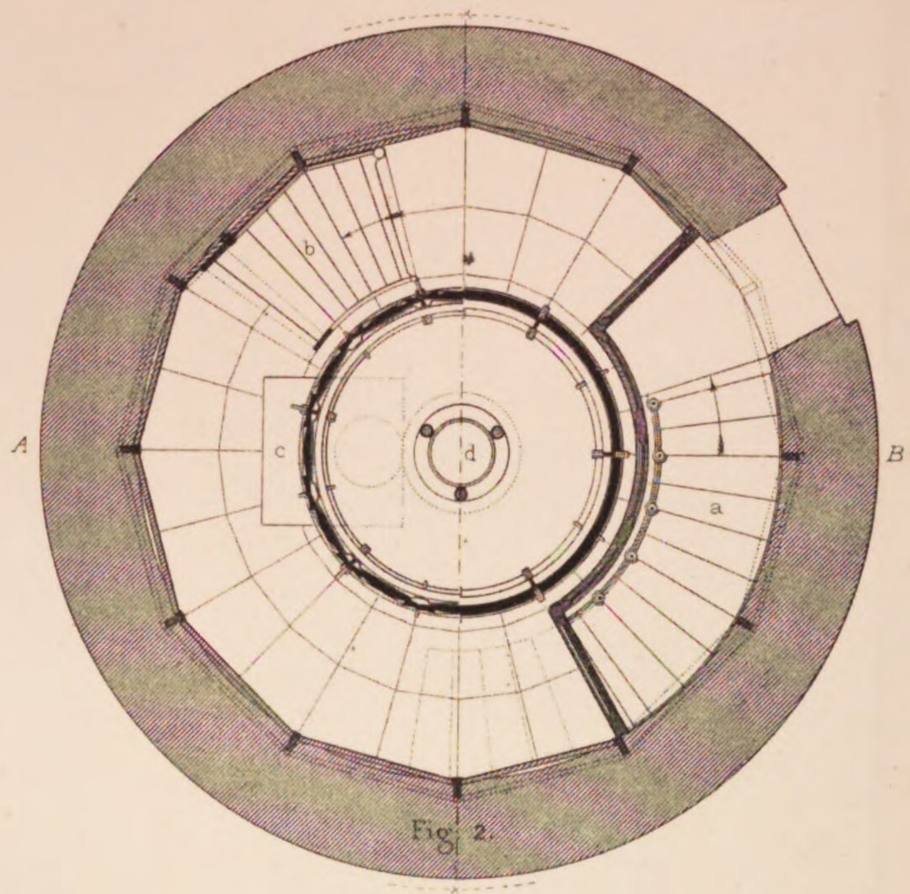



Fig. 2.

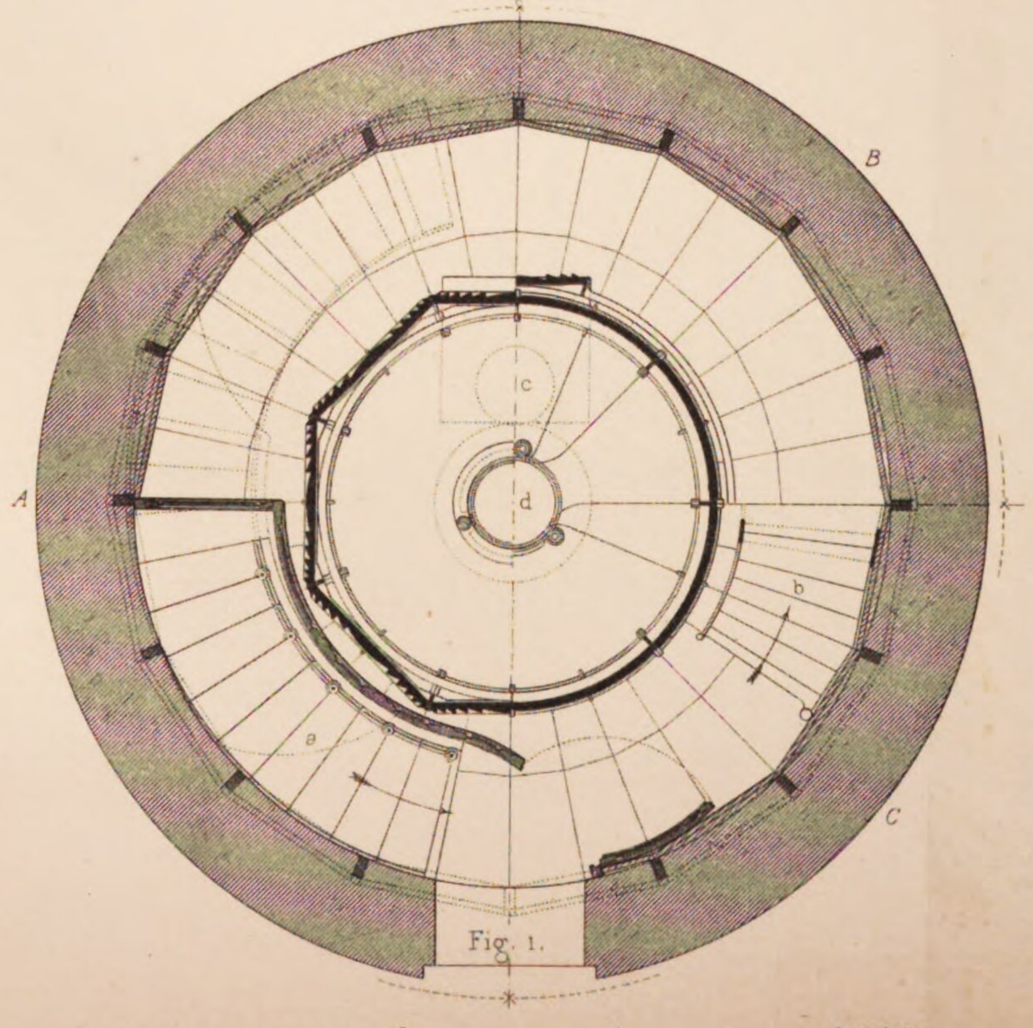



Fig. 1.

Scale of 0 1 2 meters.

# ILLUMINATING APPARATUS.

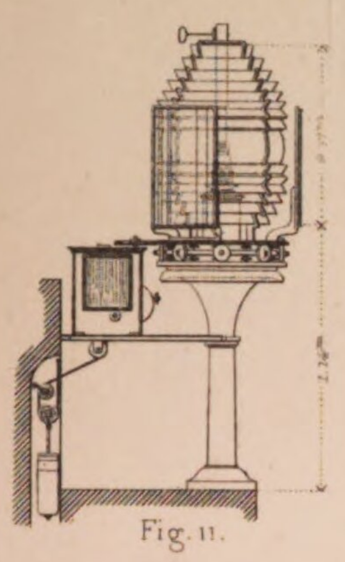


Fig. 11.

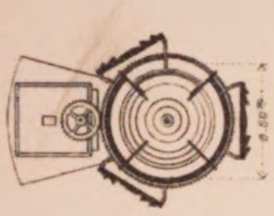


Fig. 10.

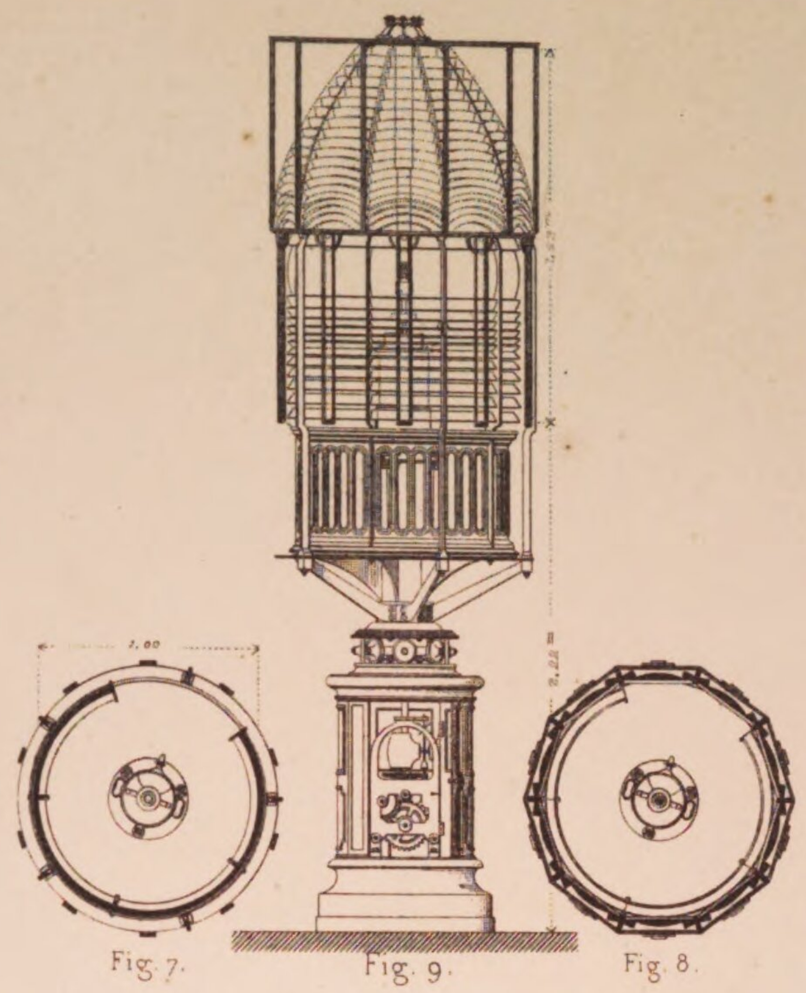


Fig. 7. Fig. 9. Fig. 8.

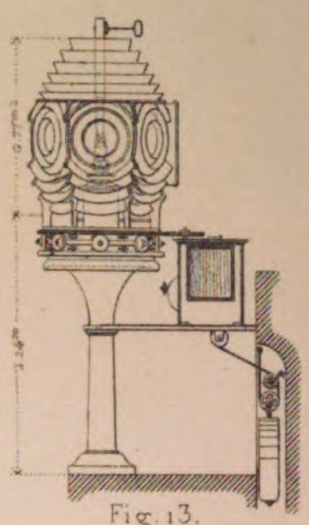


Fig. 13.

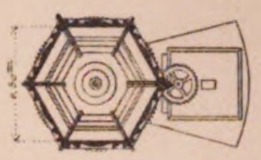


Fig. 12.

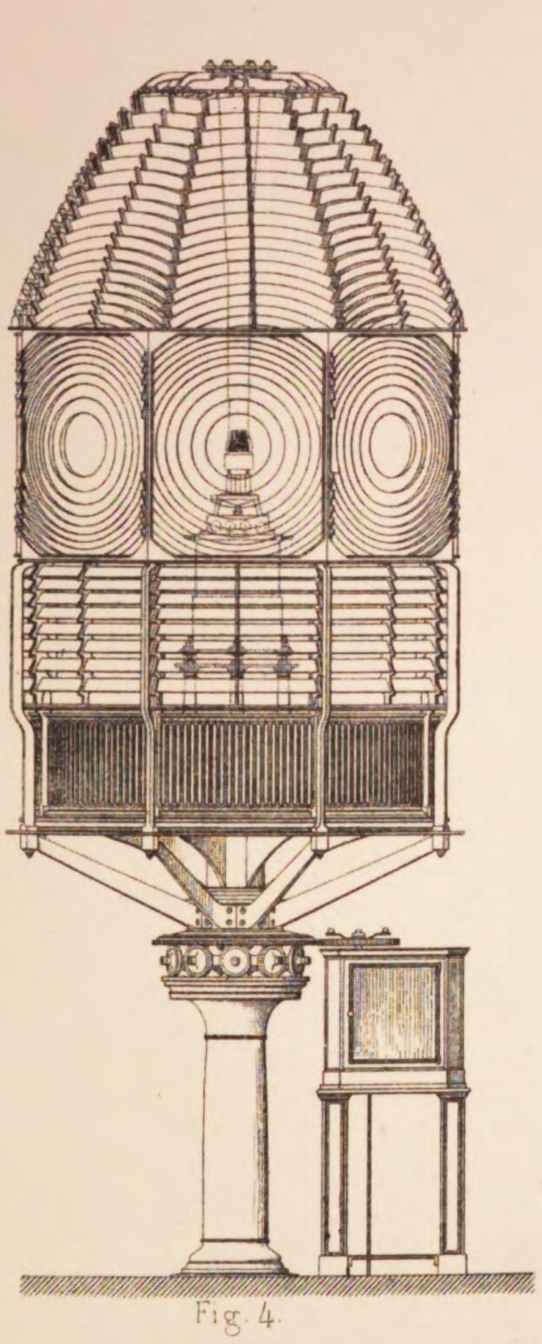


Fig. 4.

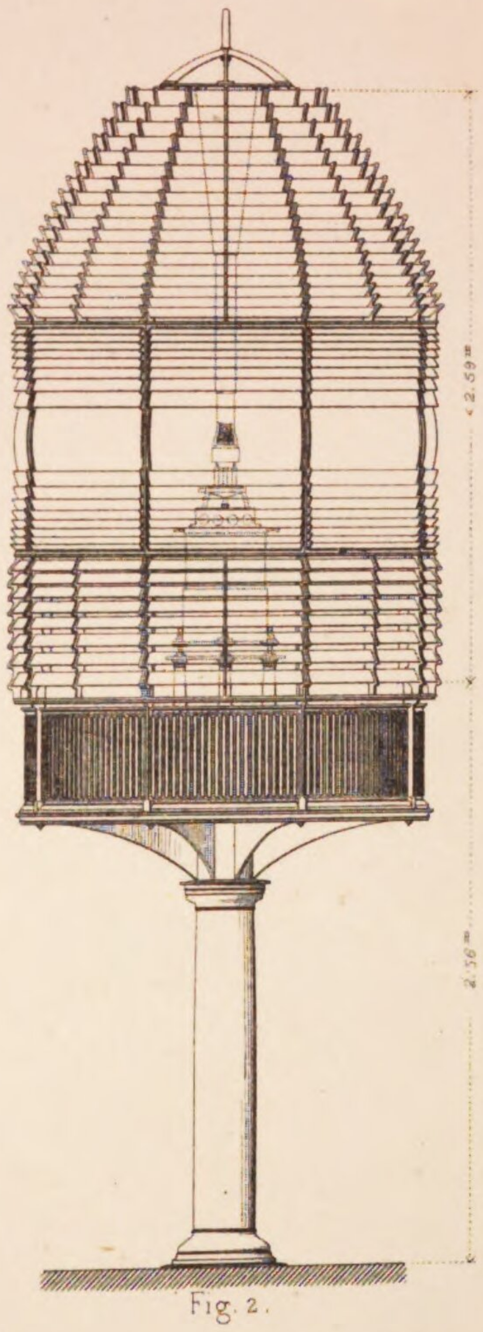


Fig. 2.

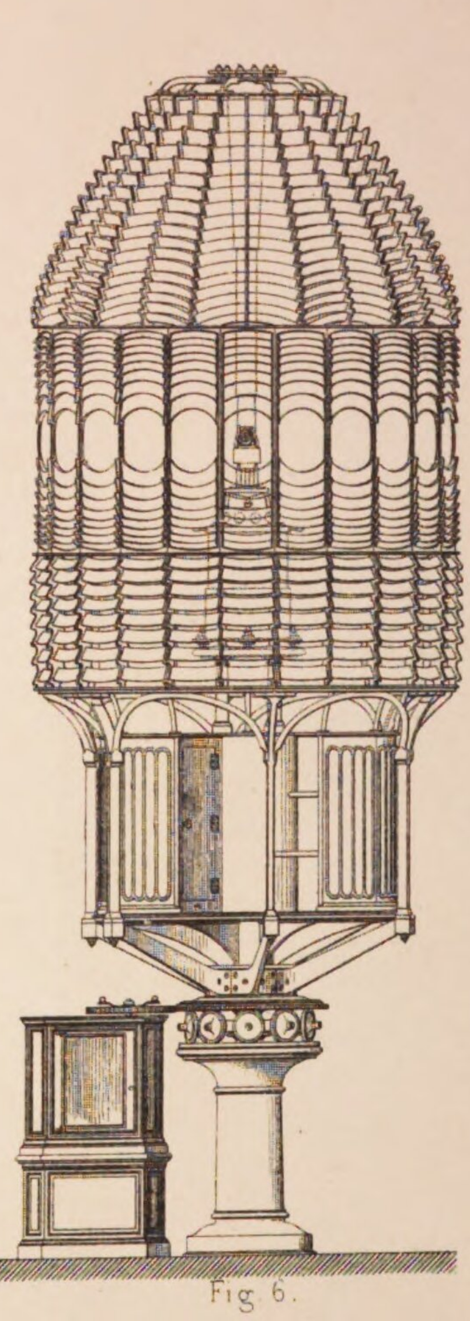


Fig. 6.

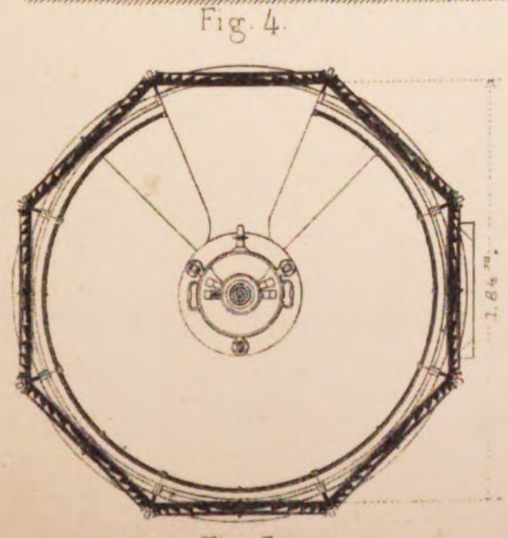


Fig. 3.

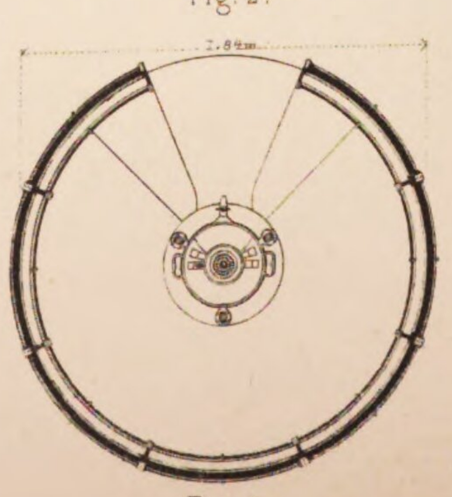


Fig. 1.

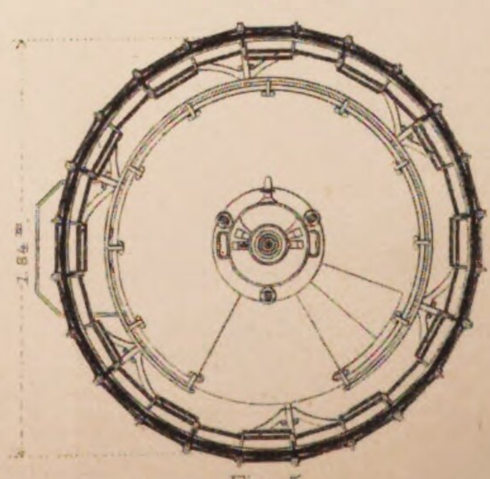


Fig. 5.

Scale of 0 1 2 3 4 5 meters.

ILLUMINATING APPARATUS.

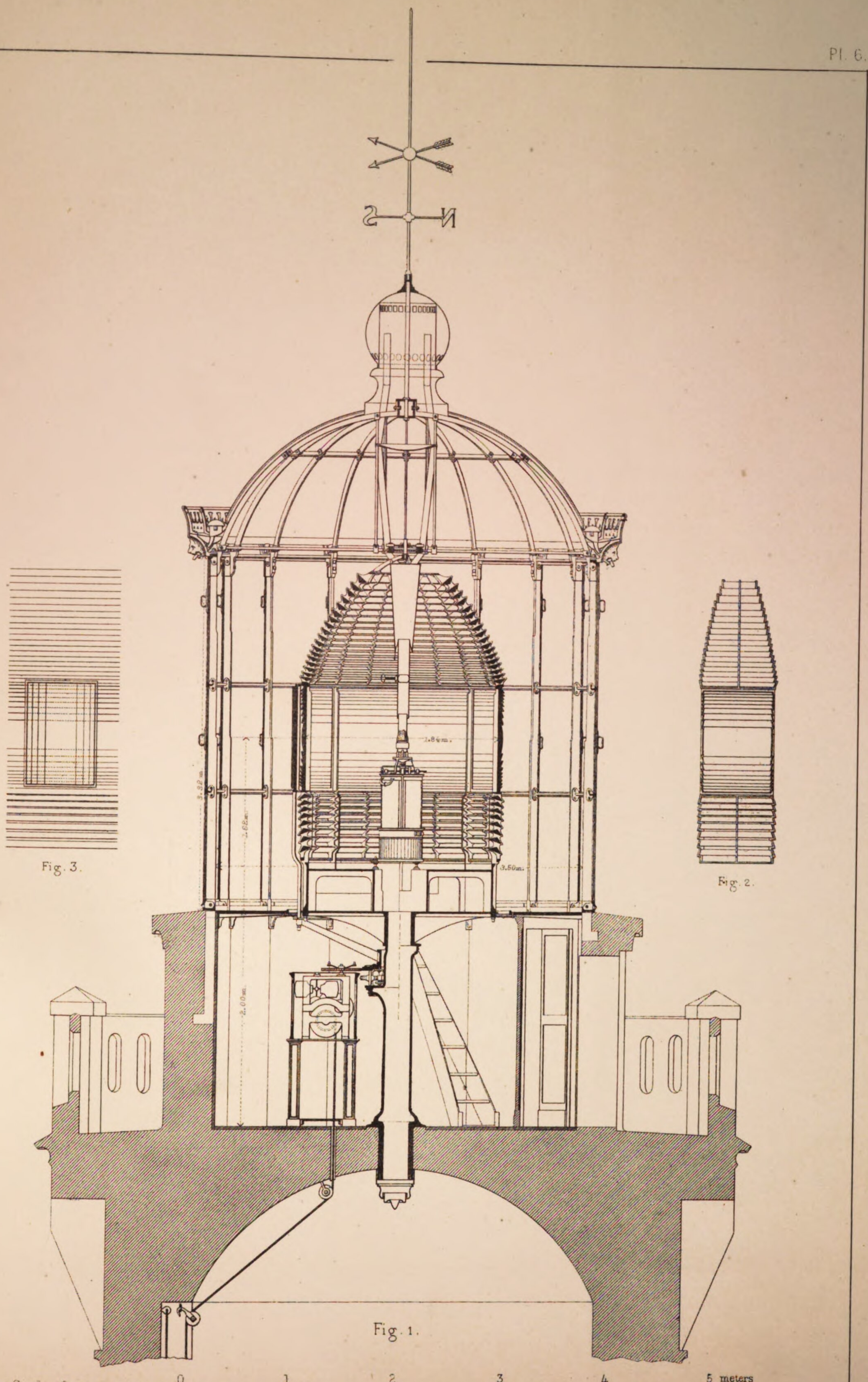
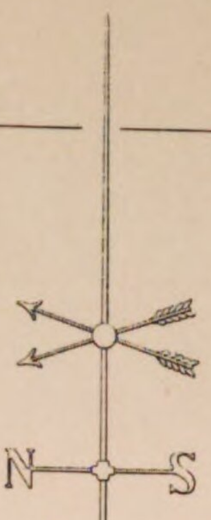


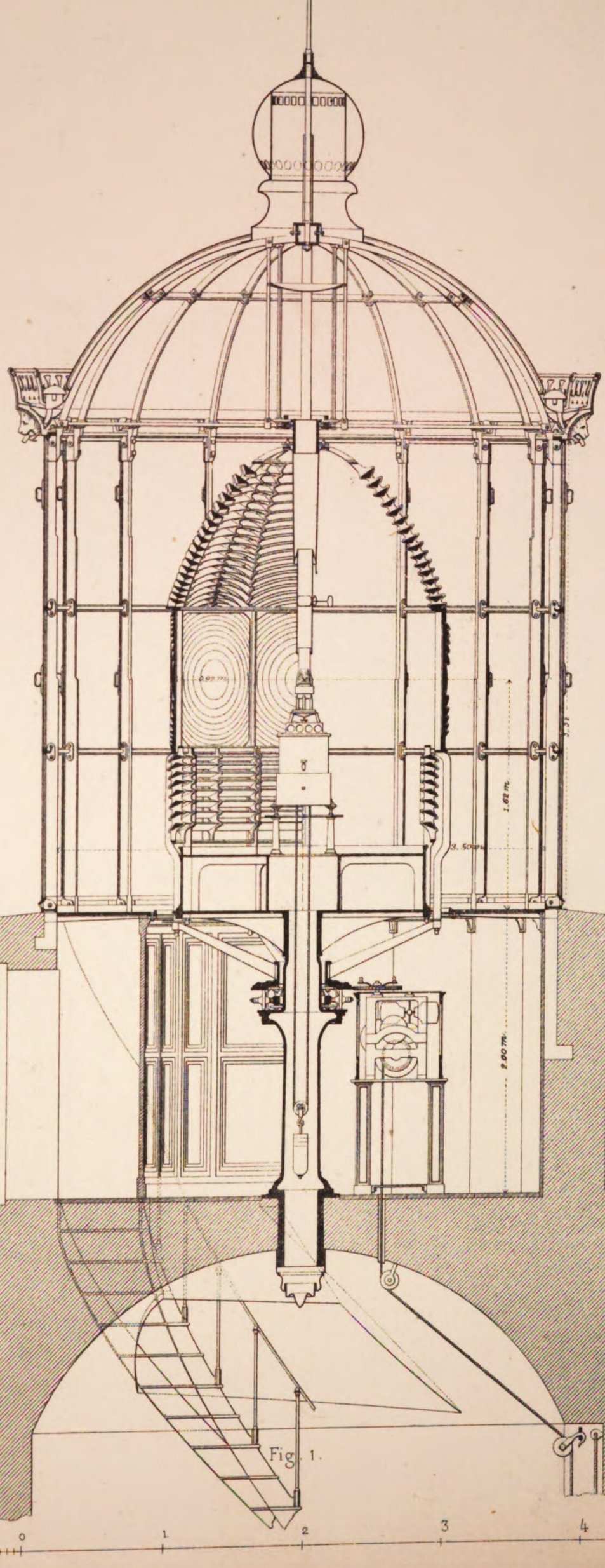

Fig. 3.

Fig. 2.

Fig. 1.

# ILLUMINATING APPARATUS. (1st Order)



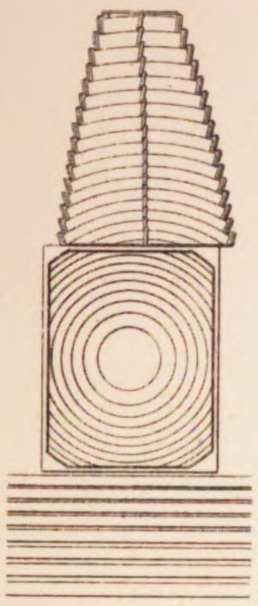



Fig. 2.

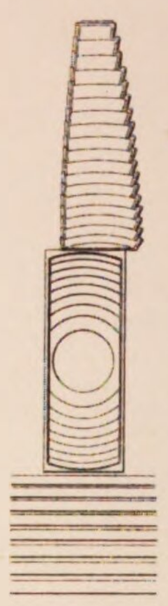


Fig. 3.



Fig. 4.

Fig. 1.

Scale of: 0 1 2 3 4 5 meters.

# ILLUMINATING APPARATUS. (1st Order)

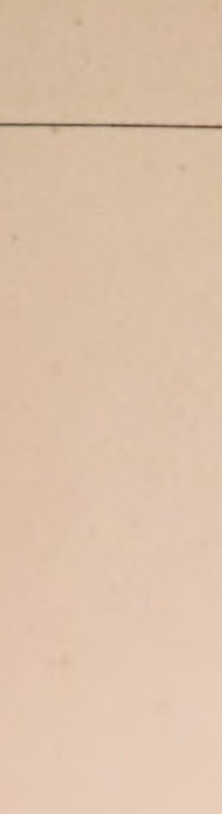


Fig. 3




Fig. 1.

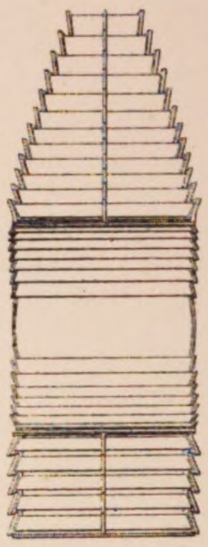


Fig. 1

# ILLUMINATING APPARATUS. (2nd Order)

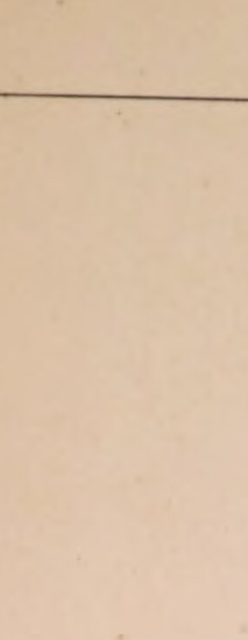


Fig. 2




Fig. 1.



Fig. 3

Scale of 0 1 2 3 4 5 meters

# ILLUMINATING APPARATUS. (3rd Order)

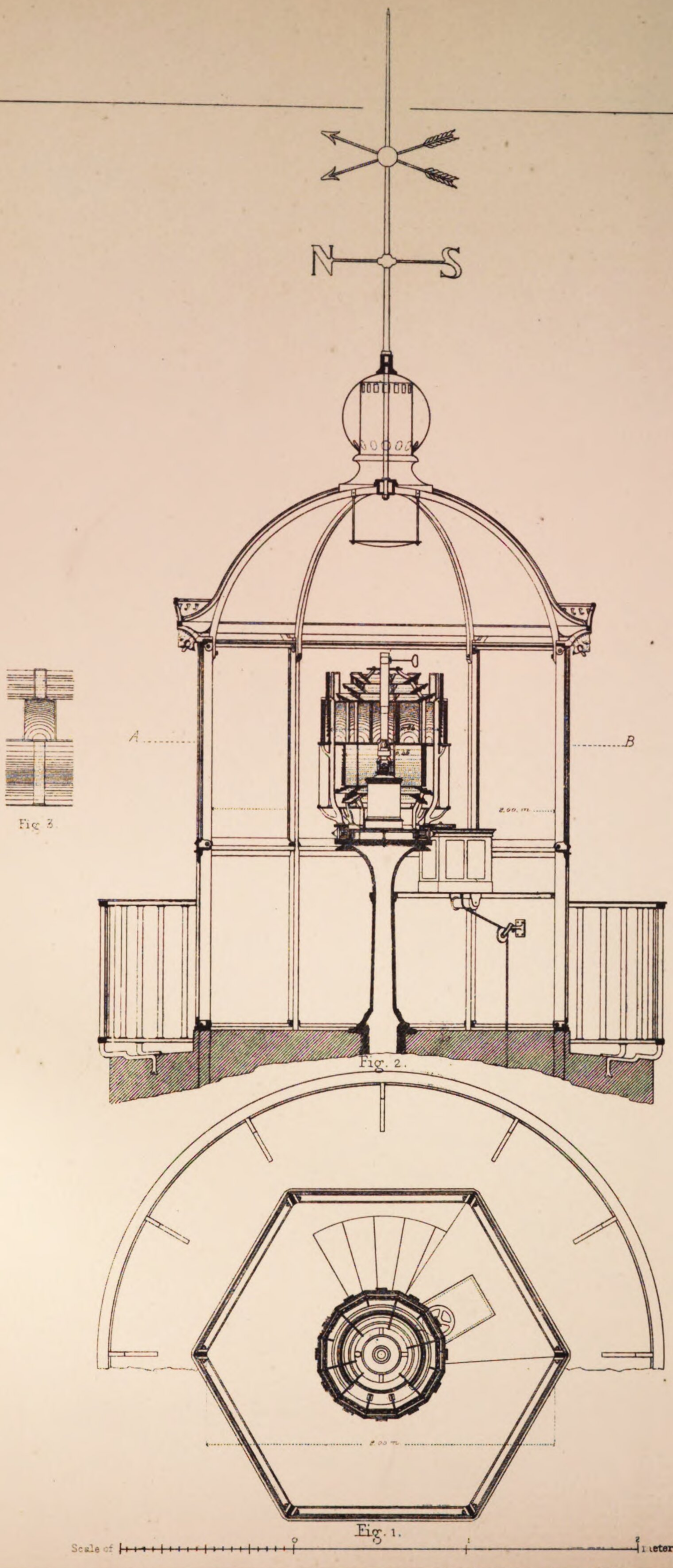



Fig. 3.

Fig. 2.

Fig. 1.

Scale of

# ILLUMINATING APPARATUS. (3rd Order. Small model)

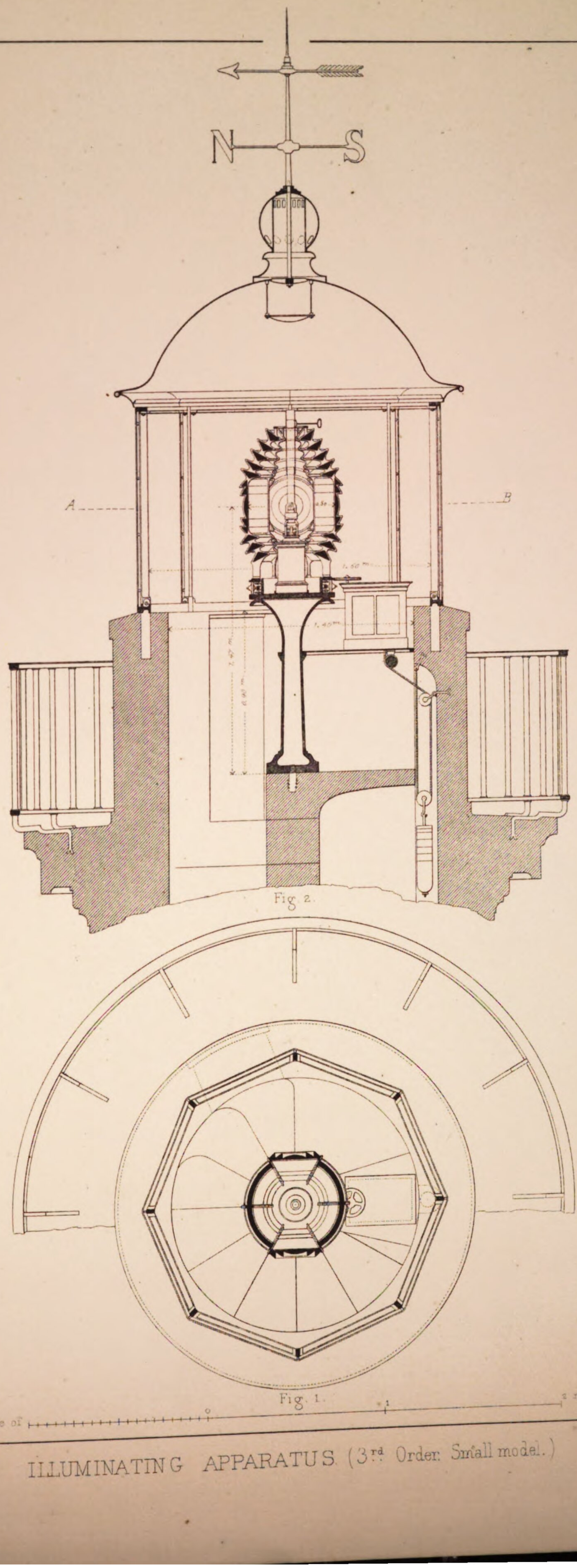



Fig. 2.




Fig. 1.

# ILLUMINATING APPARATUS. (3rd Order. Small model.)

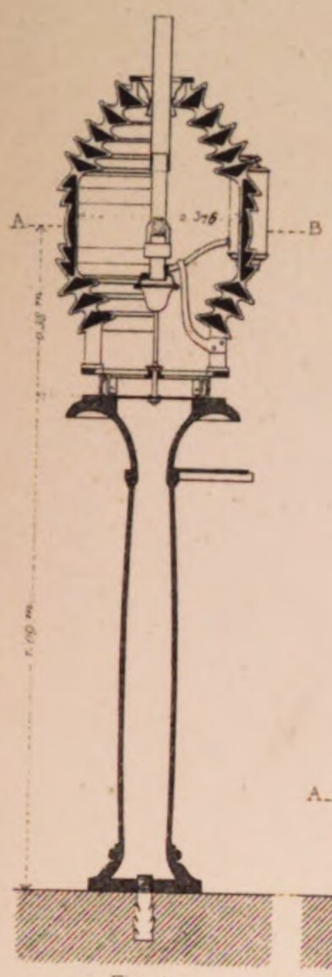



Fig. 2

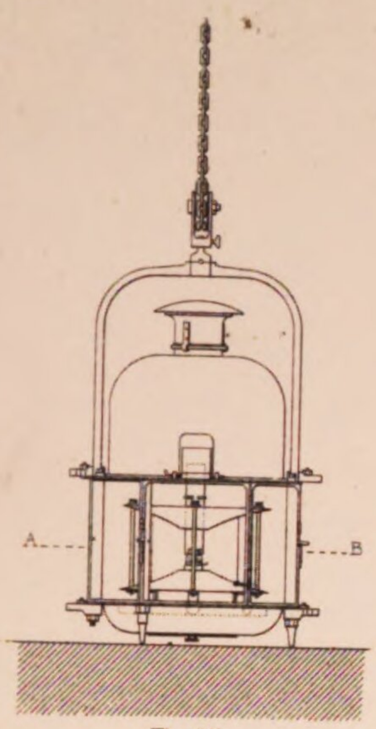



Fig. 15.

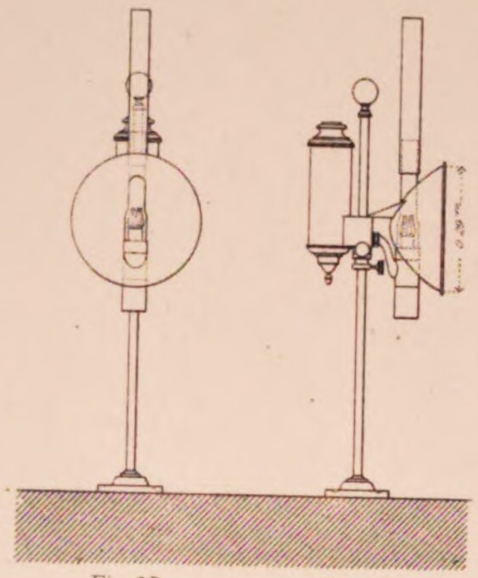


Fig. 12 Fig. 13.

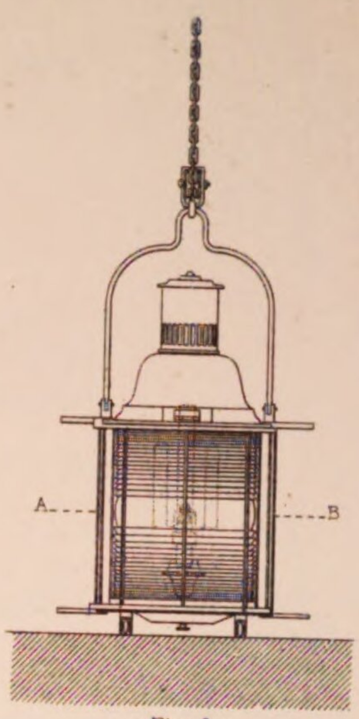



Fig. 6.

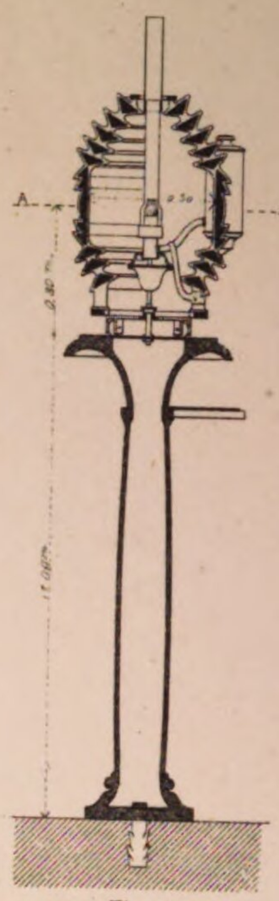



Fig. 4.




Fig. 1.

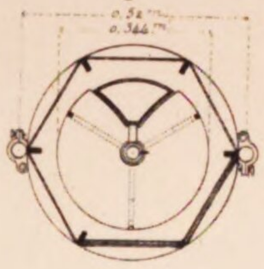


Fig. 14.



Fig. 11.

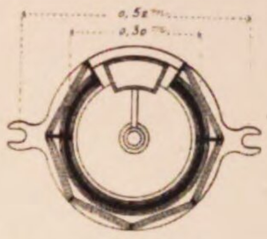


Fig. 5.




Fig. 3.

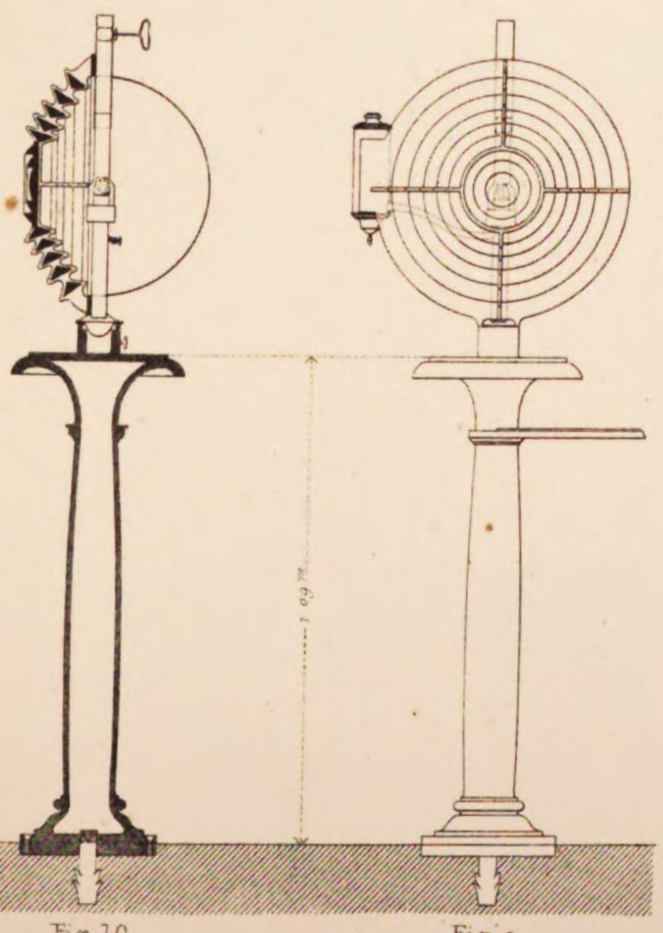



Fig. 10.



Fig. 9.

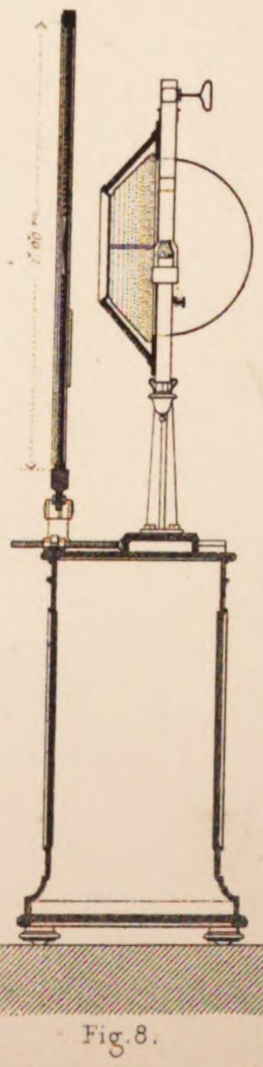


Fig. 8.

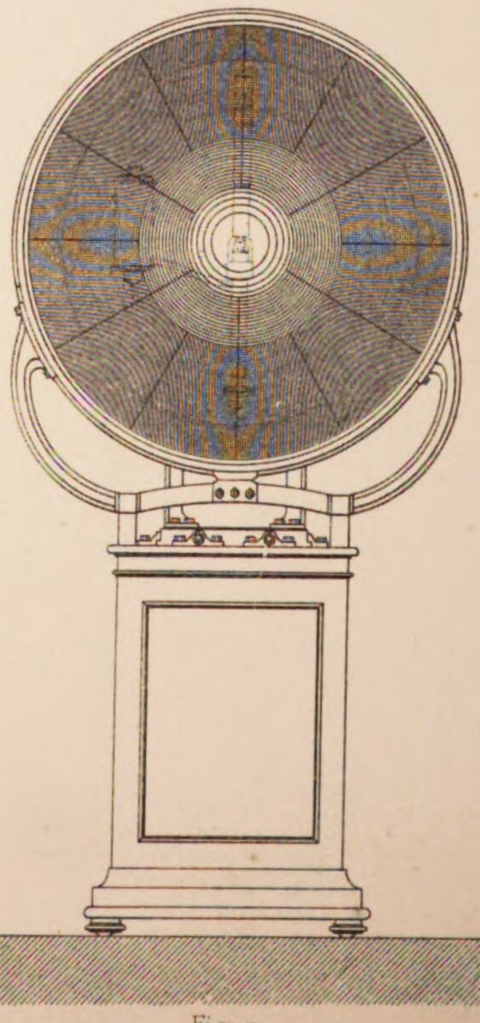


Fig. 7.

Scale of 0 1 2 meters

# ILLUMINATING APPARATUS. (4th Order)

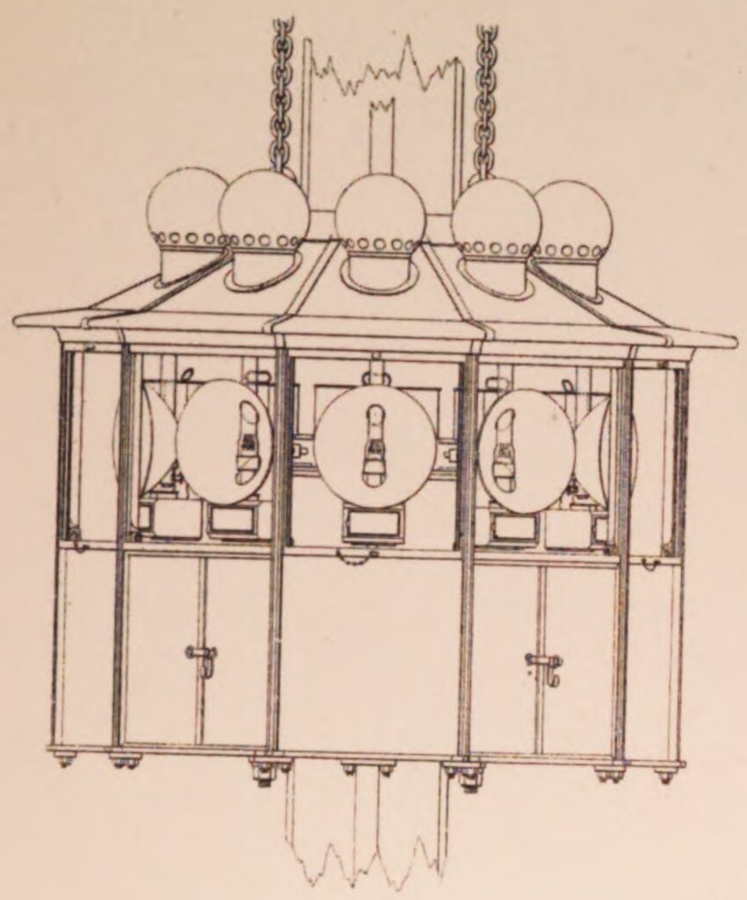


Fig. 1.

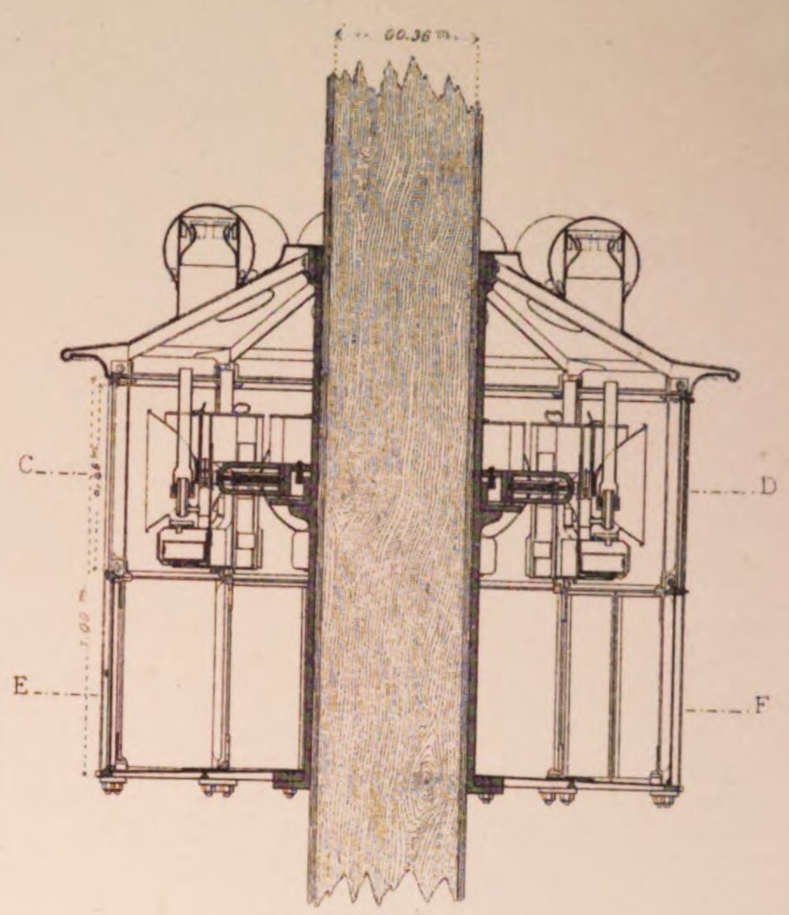



Fig. 2.

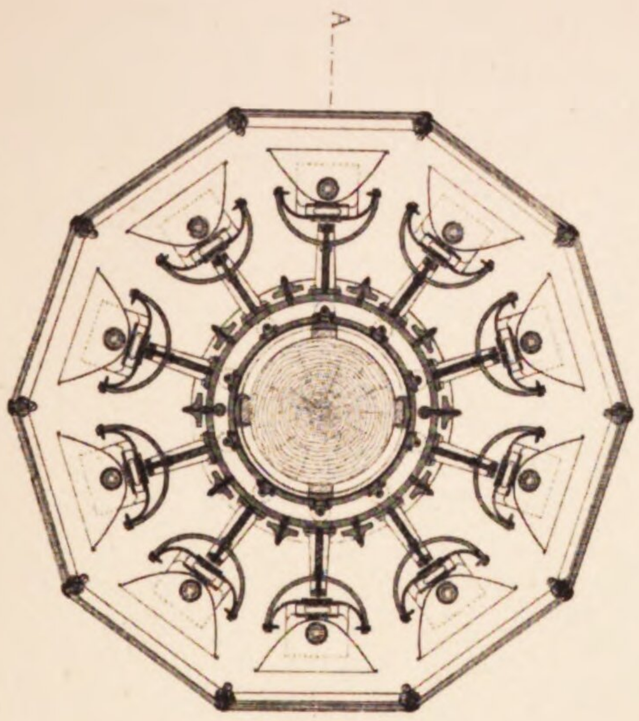



Fig. 3.

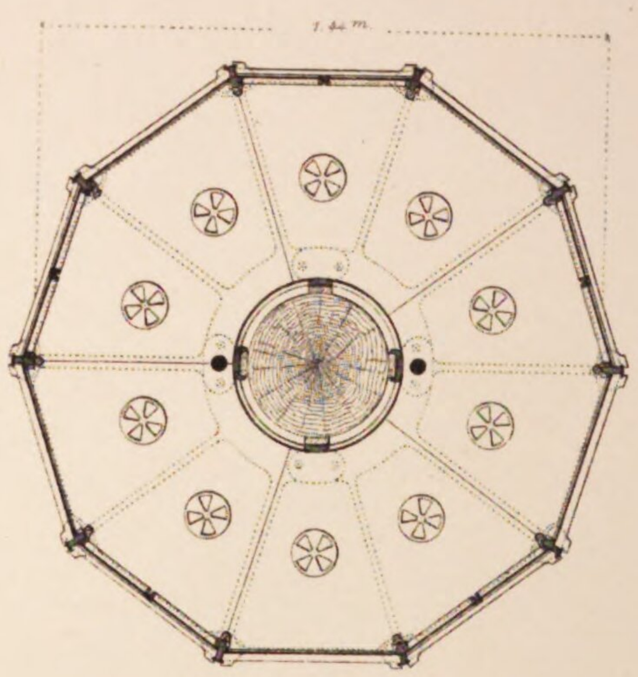



Fig. 4.

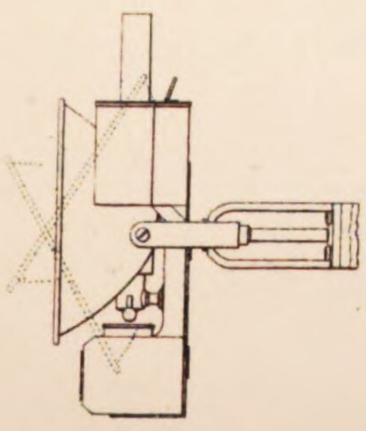


Fig. 6.

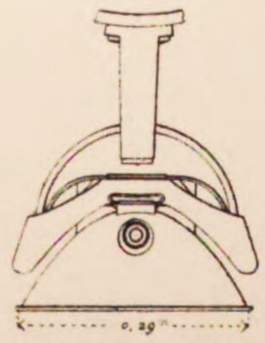



Fig. 7.

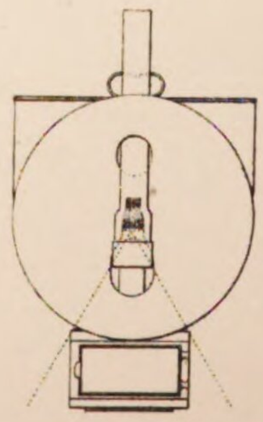
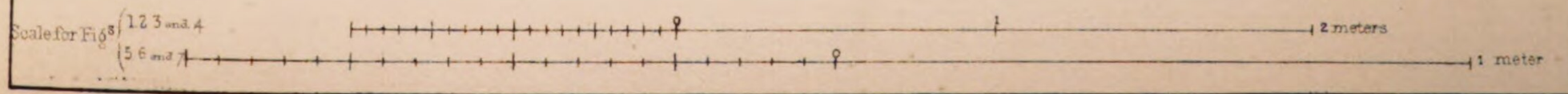


Fig. 5.




ILLUMINATING APPARATUS. (Floating Light)

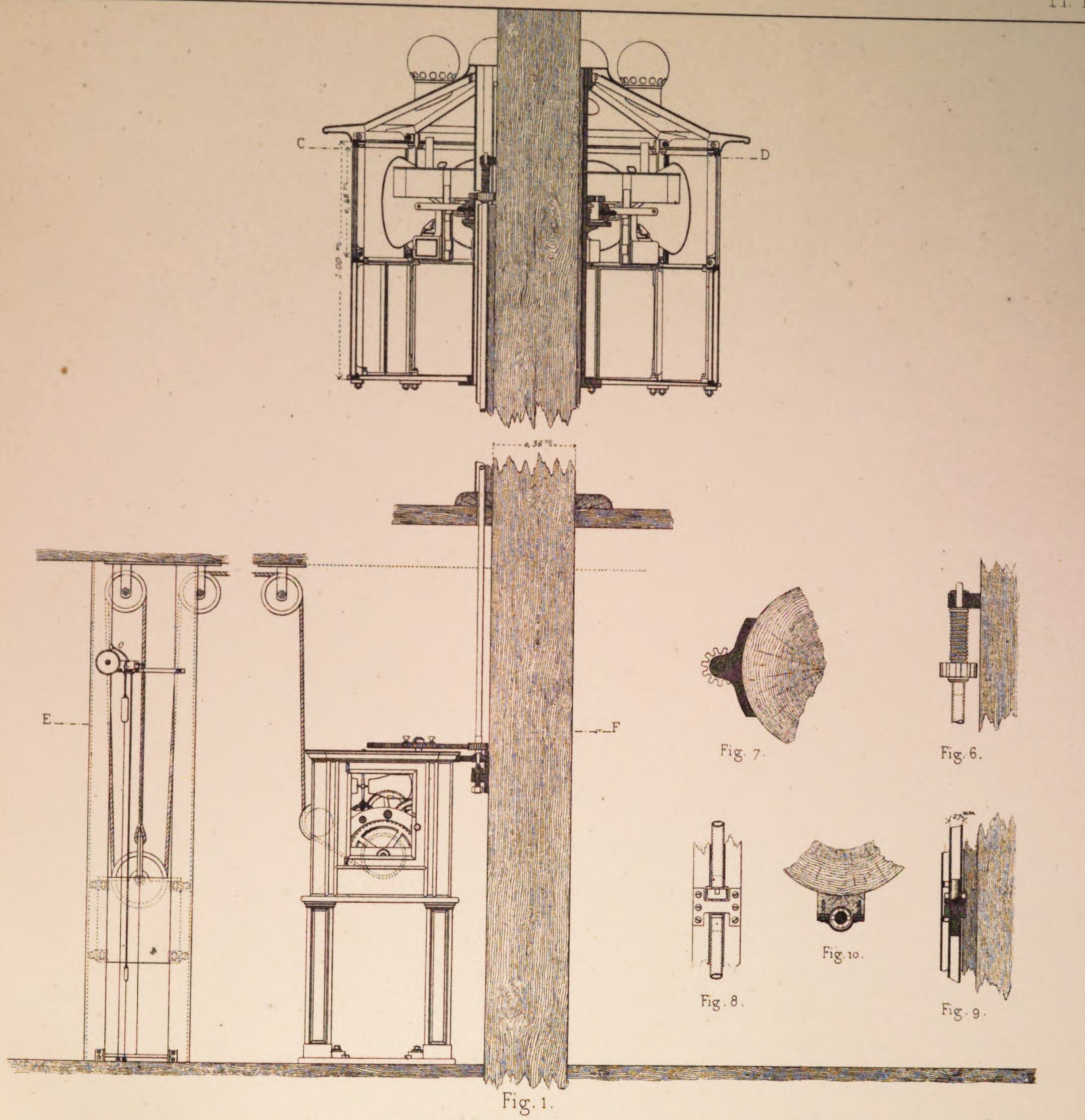



Fig. 1.



Fig. 7.



Fig. 6.



Fig. 8.



Fig. 10.



Fig. 9.

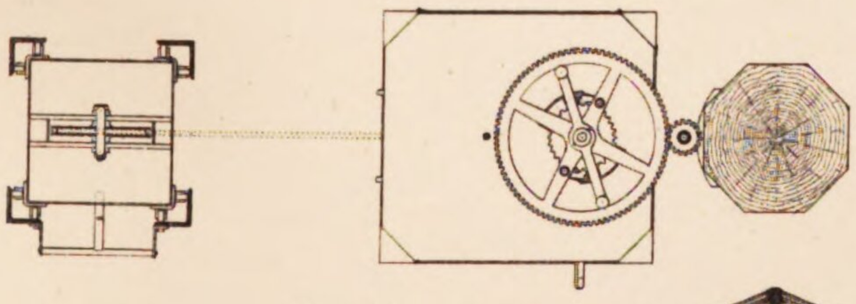


Fig. 3.

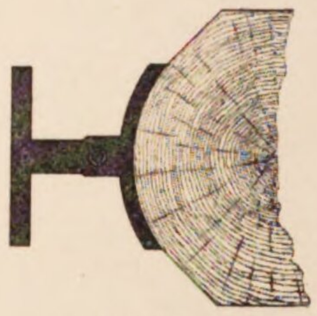


Fig. 5.

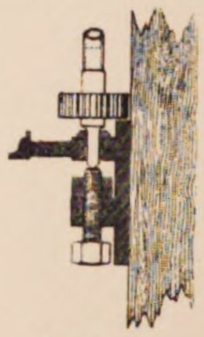


Fig. 4.

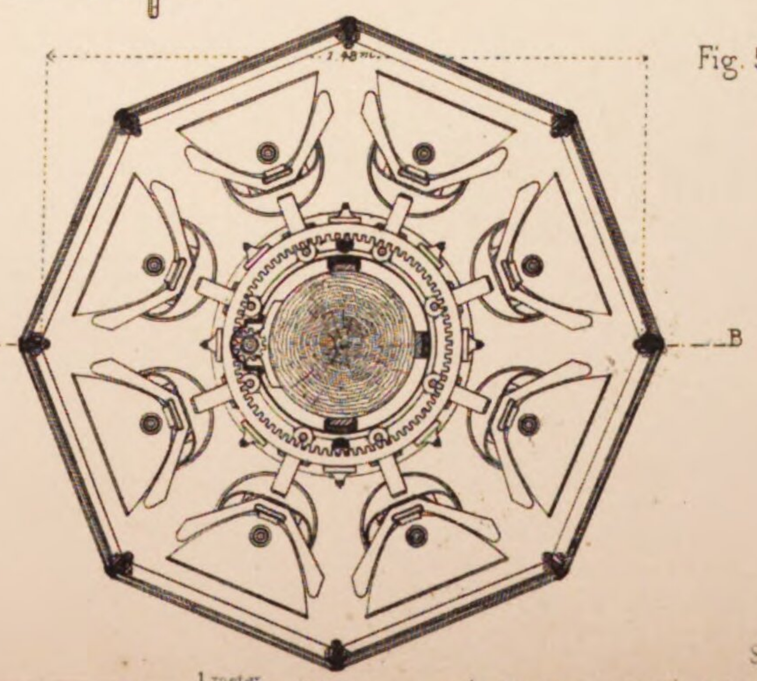



Fig. 2.

Scale for Figs 1. 2. and 3.

1 meter

Scale for Figs 4 to 9.

1 meter

# ILLUMINATING APPARATUS. (Floating Light)

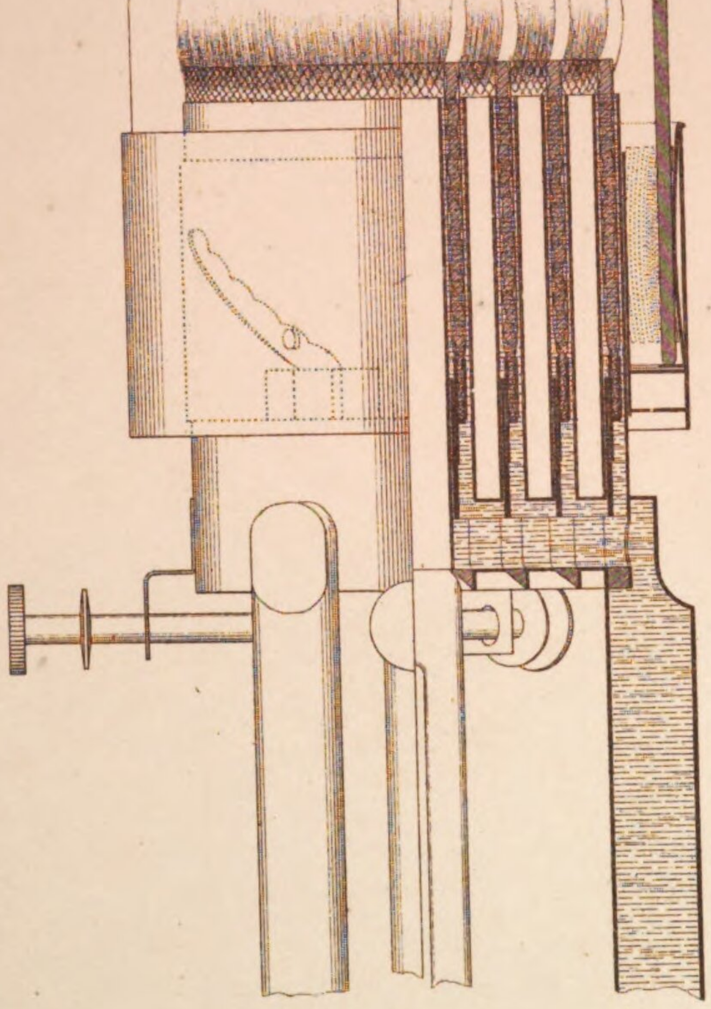


Fig. 2.

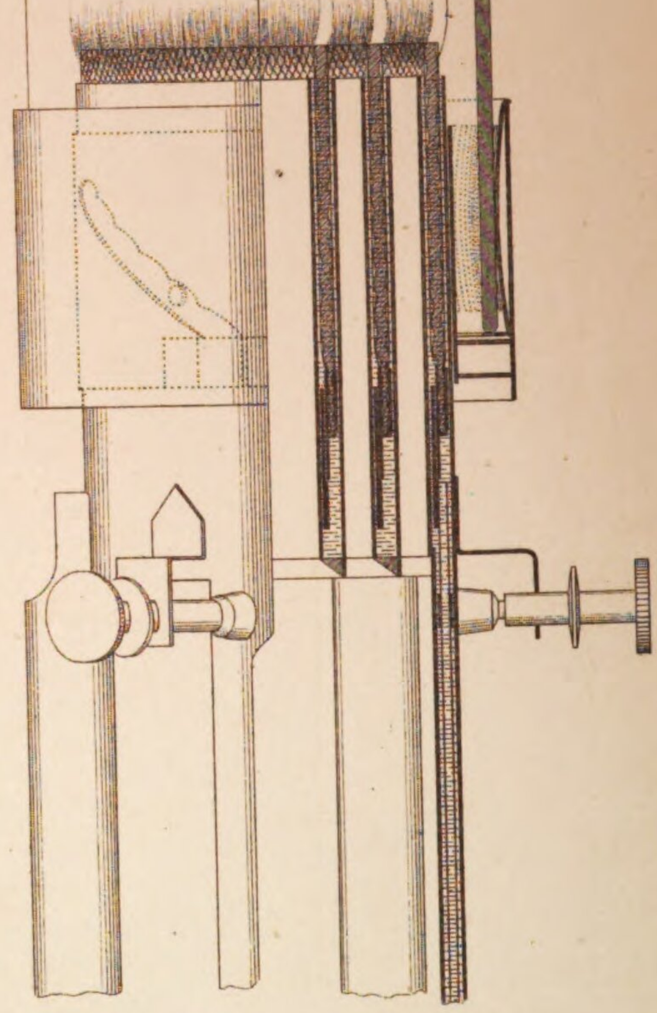


Fig. 4.



Fig. 6.

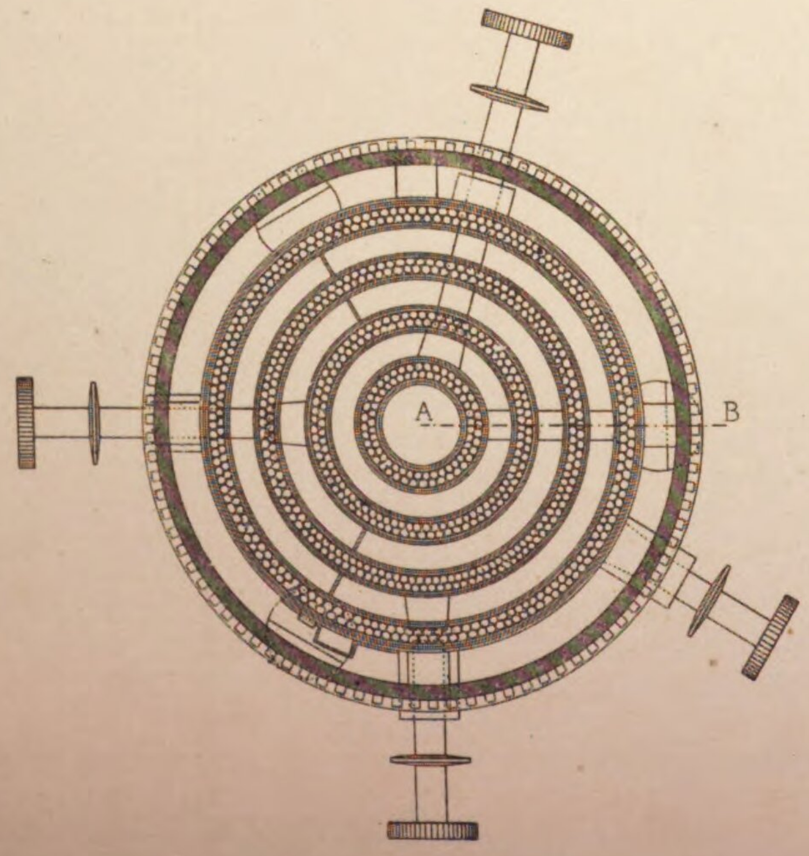



Fig. 1.

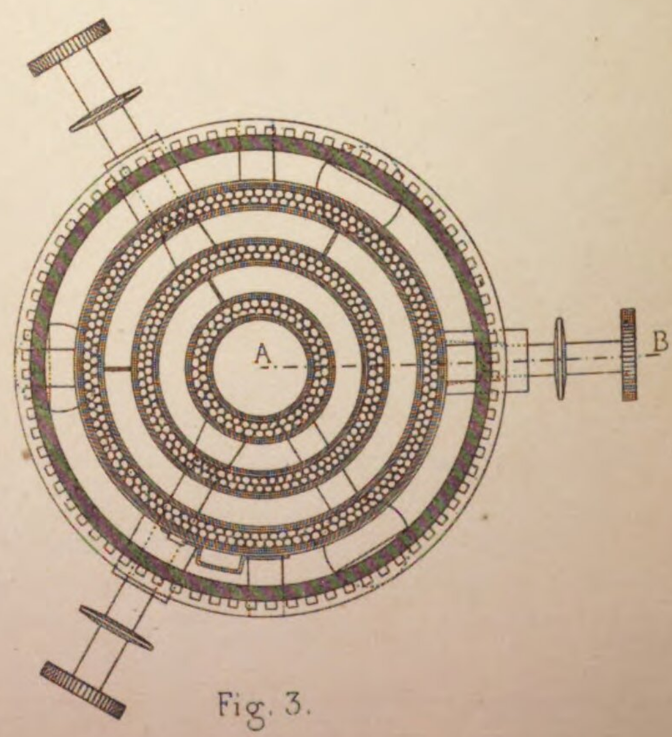



Fig. 3.



Fig. 5.

Scale of 0 1 2 3 4 5

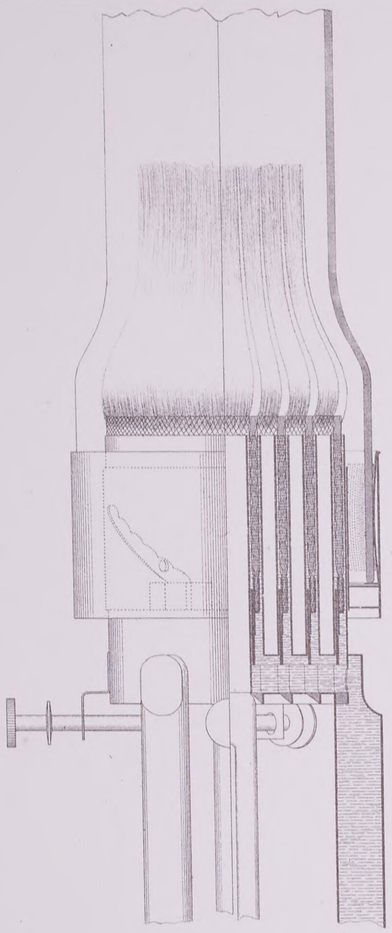


Fig. 2.

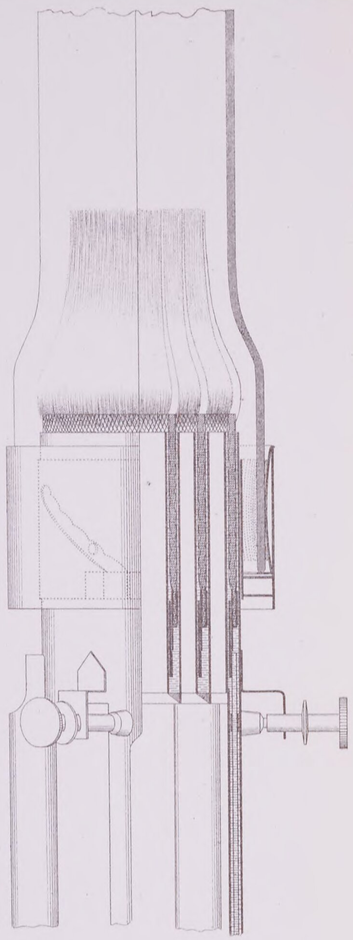


Fig. 4.

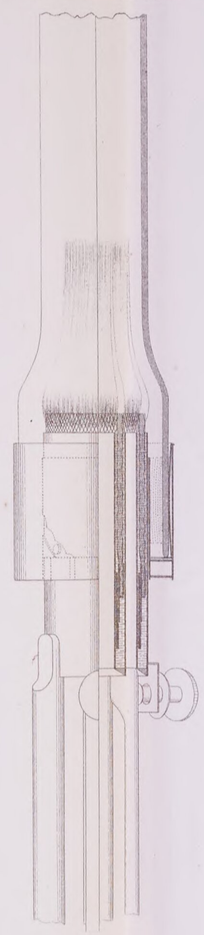


Fig. 6.

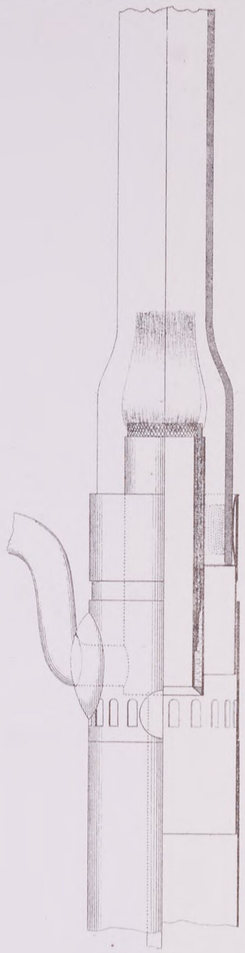


Fig. 8.

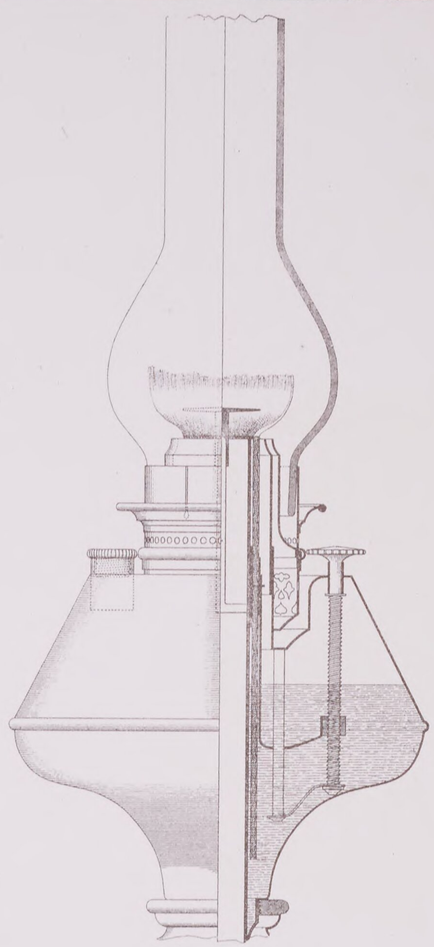


Fig. 10.

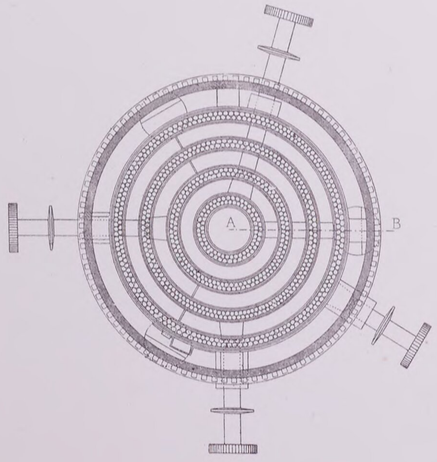



Fig. 1.

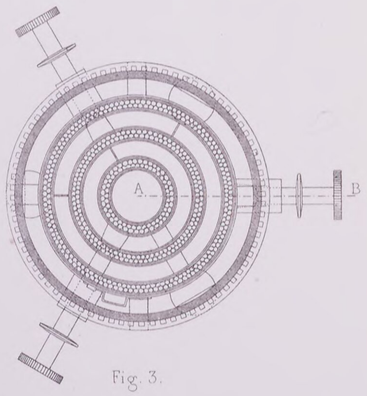



Fig. 3.

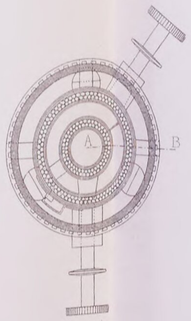



Fig. 5.

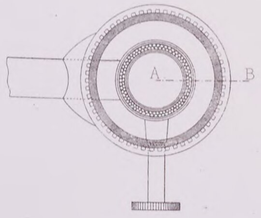



Fig. 7.

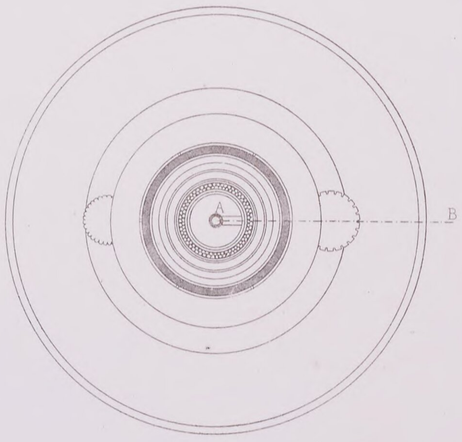



Fig. 9.

Scale of 0 1 2 3 4 5 10 centimeters



Fig. 5

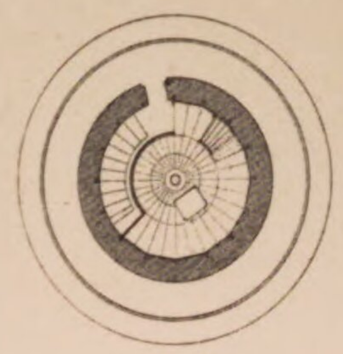


Fig. 6.

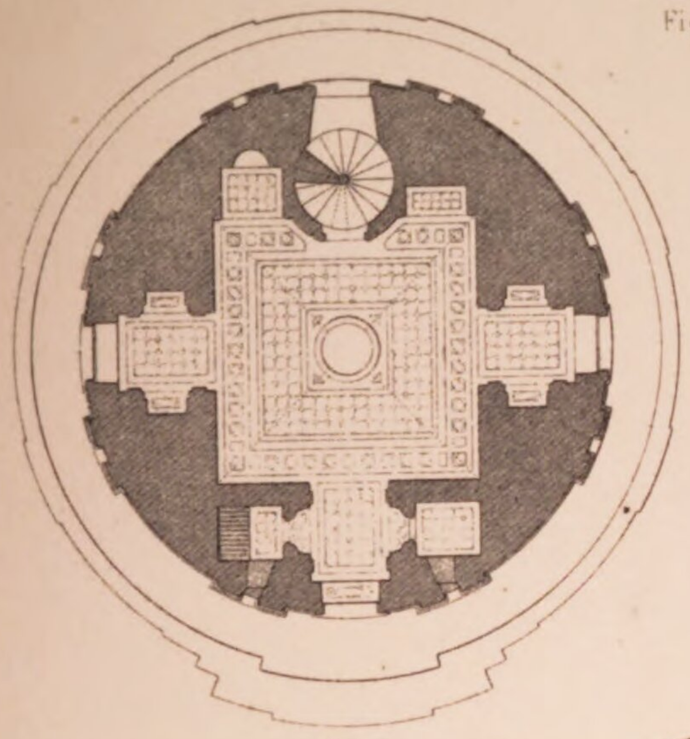


Fig. 2.

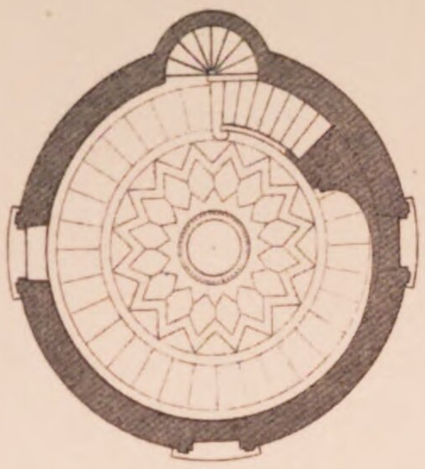


Fig. 4.

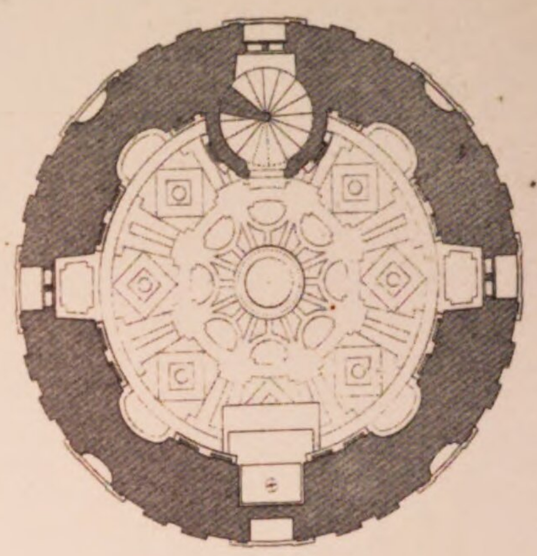


Fig. 3.

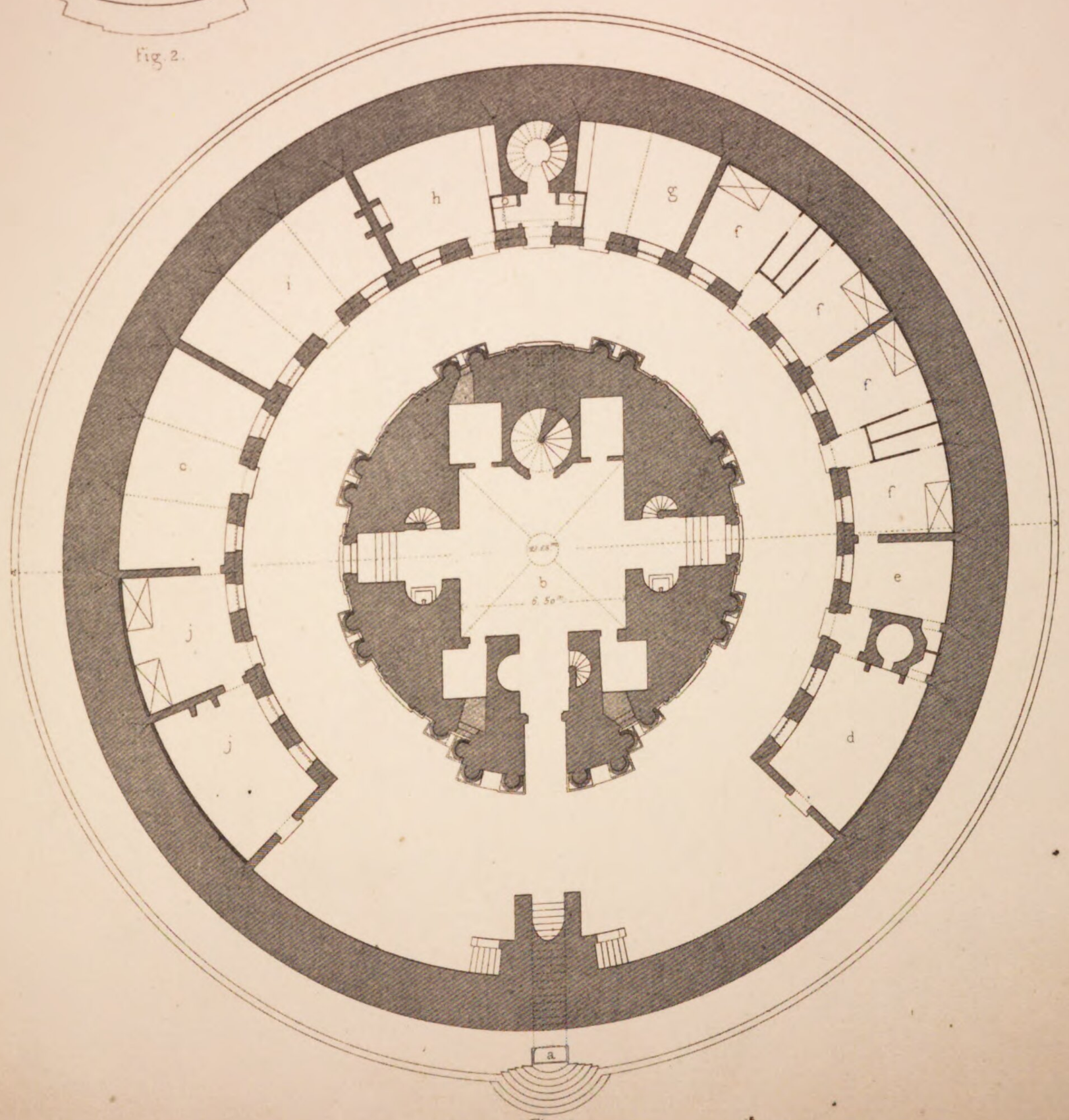
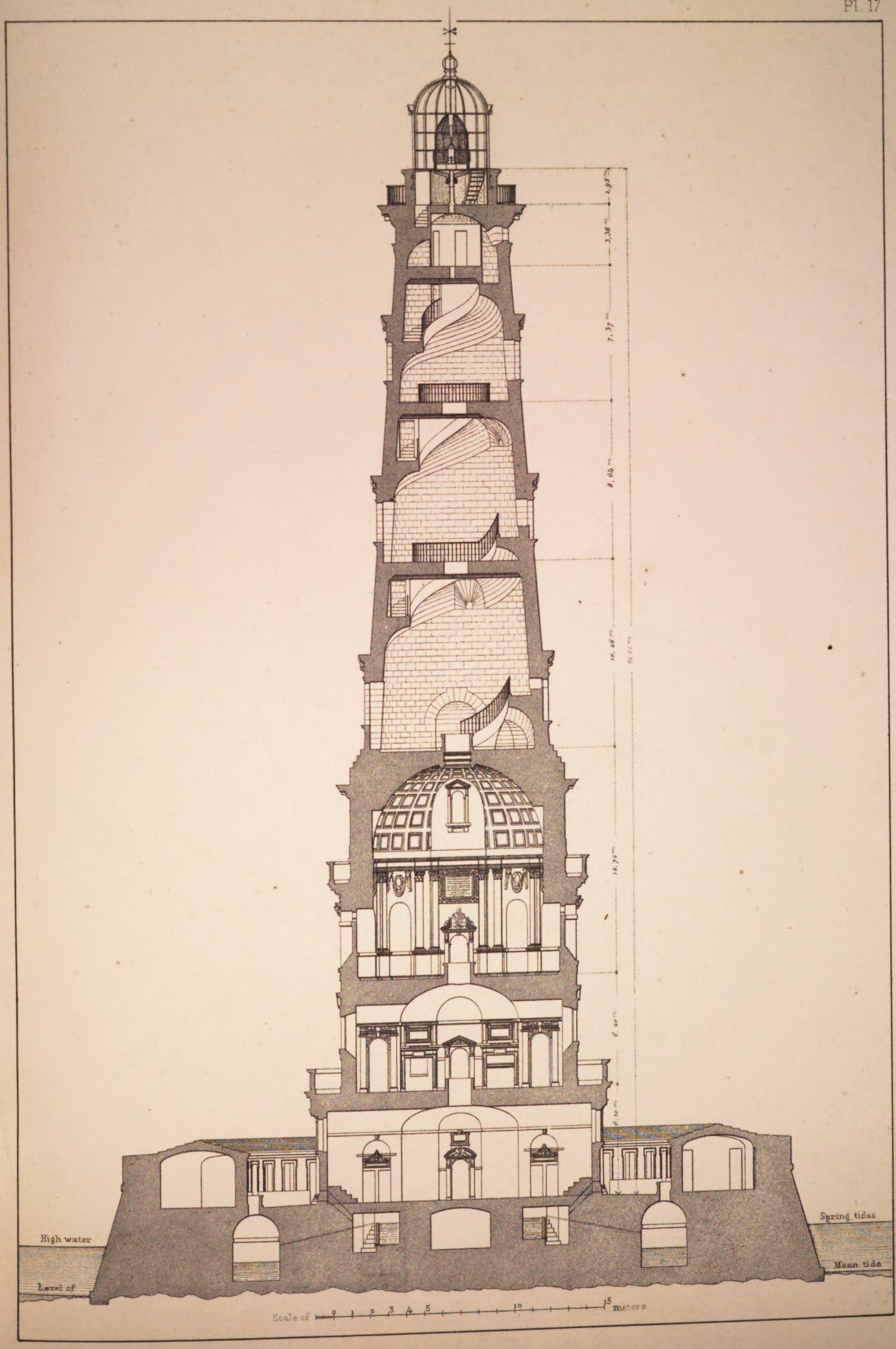
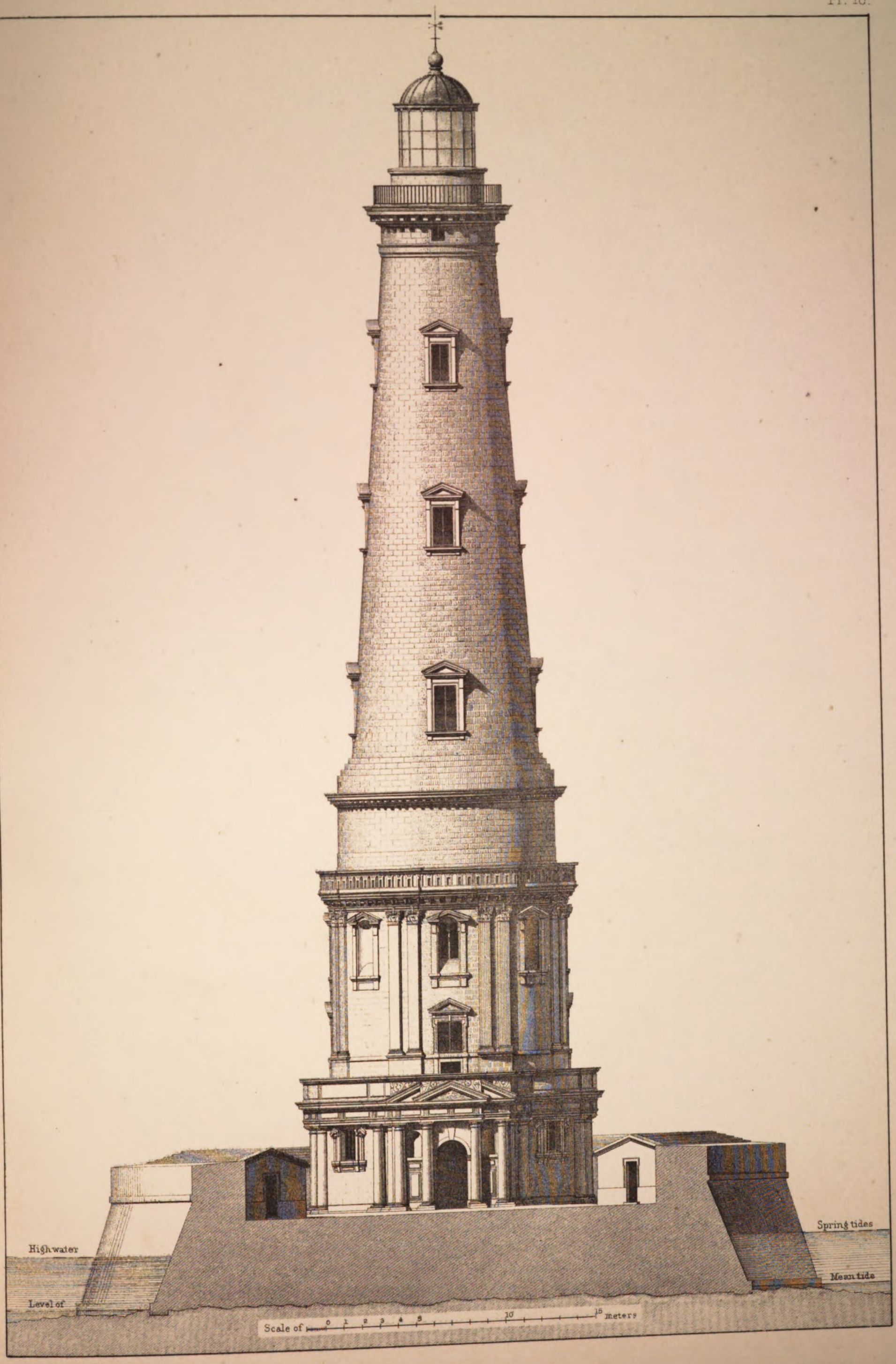



Fig. 1.

# LIGHT HOUSE OF CORDOUAN.




LIGHT HOUSE OF CORDOUAN.




LIGHT HOUSE OF CORDOUAN.

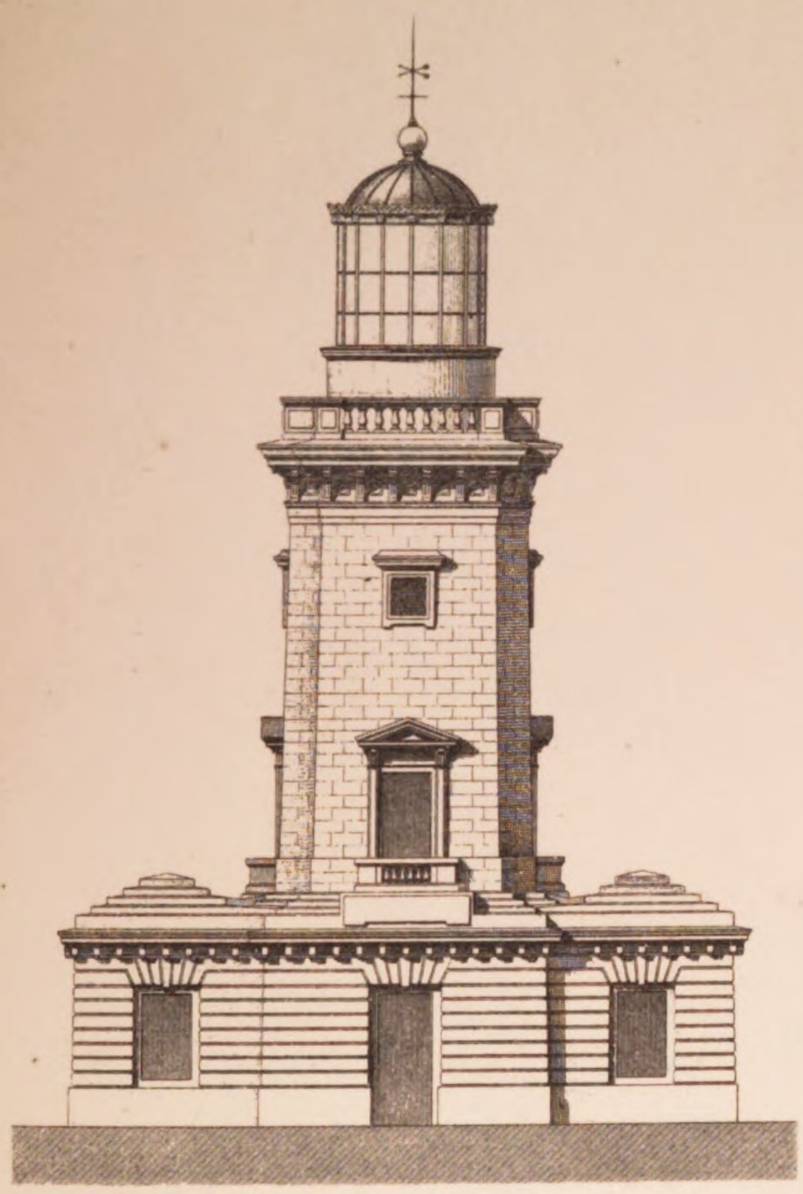


Fig. 1.

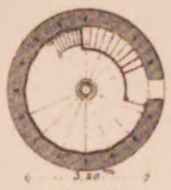


Fig. 3.

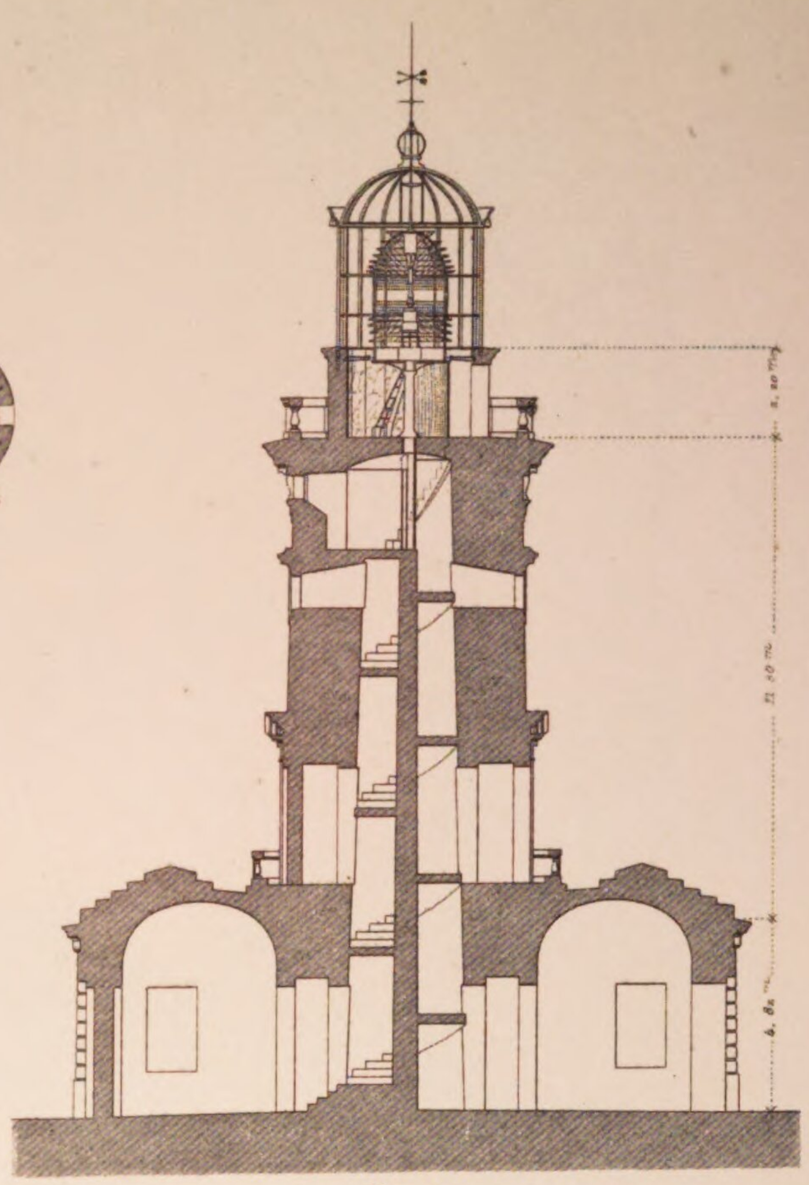


Fig. 2.

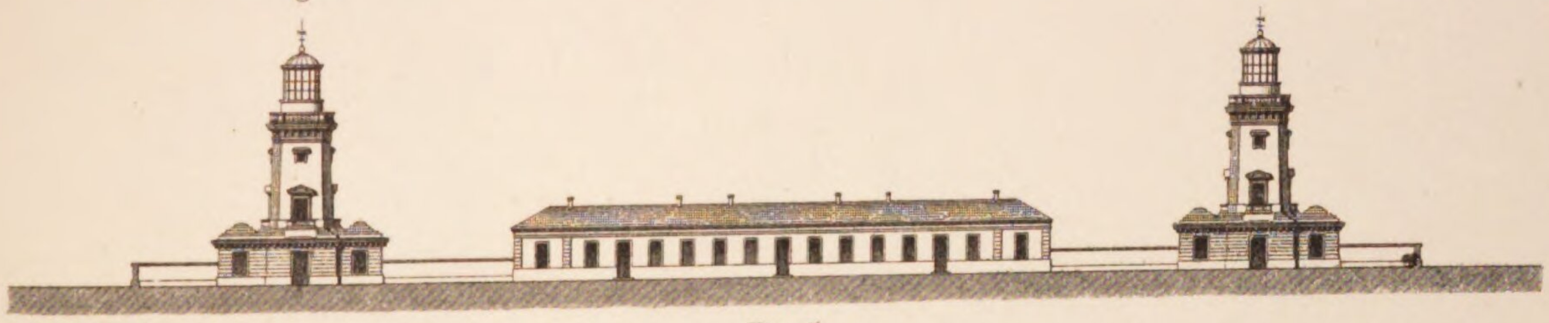


Fig. 5.

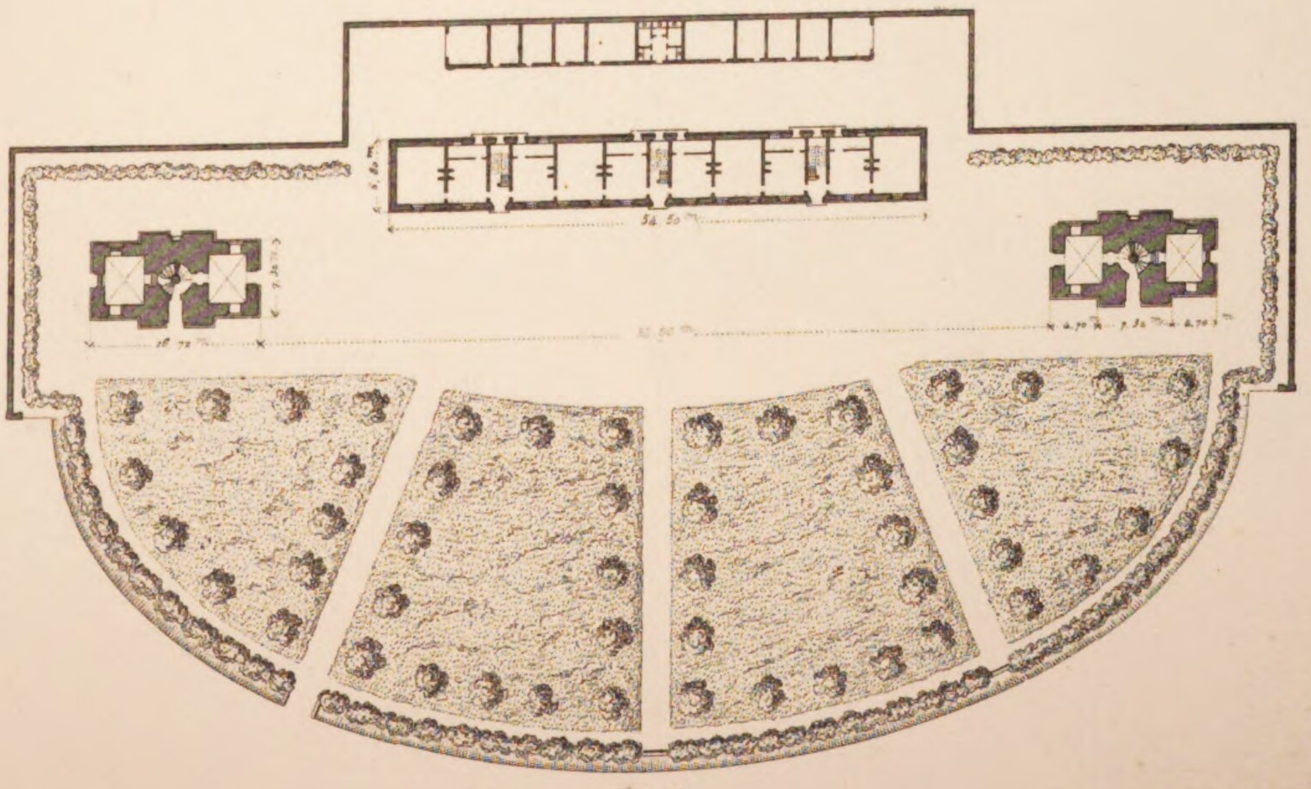


Fig. 4.

Scale for Figs. { 4 and 5 / 1 2 and 3 }

# LIGHT HOUSES OF LA HÈVE

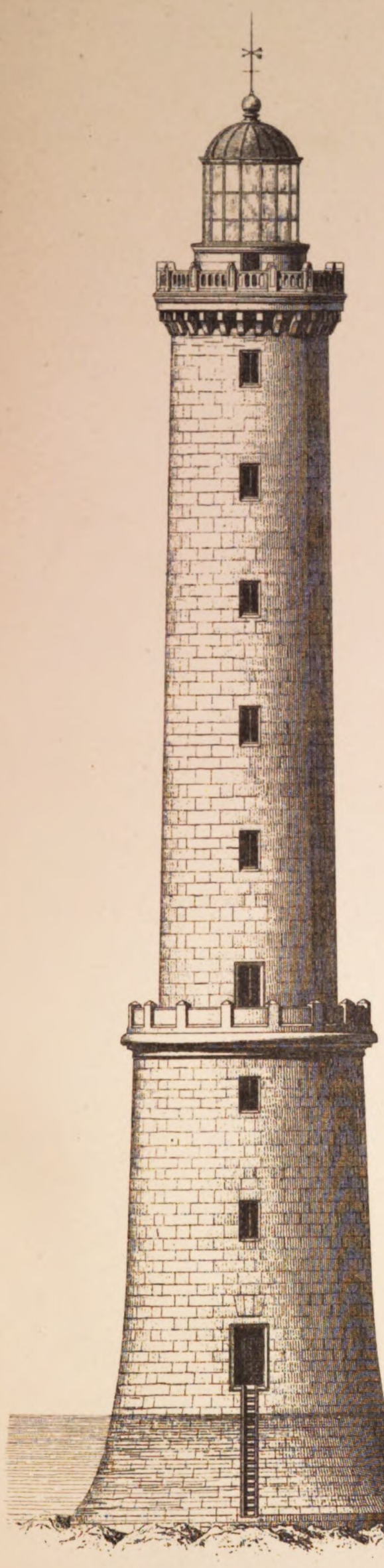


Fig. 1

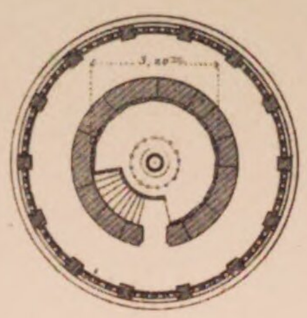


Fig. 6.

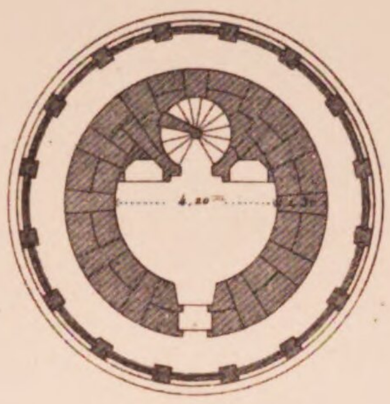


Fig. 5.

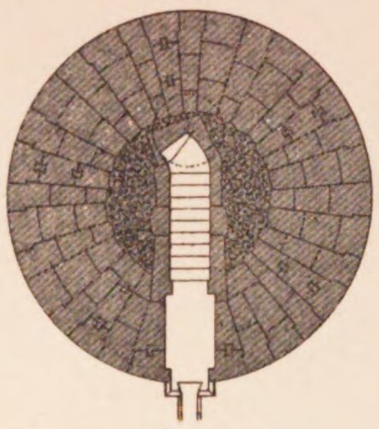


Fig. 4.

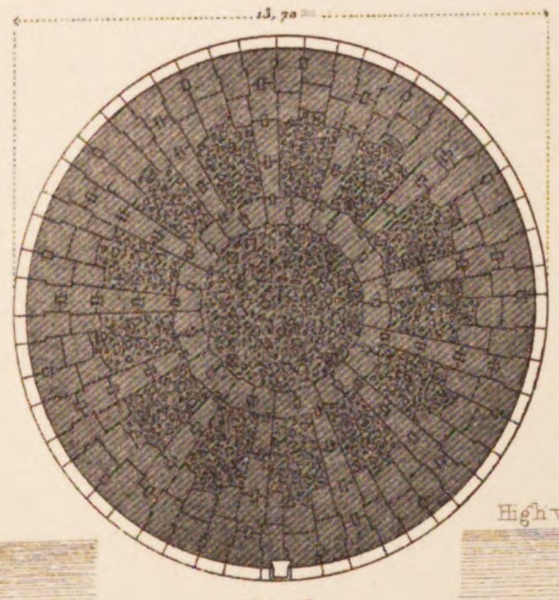


Fig. 3.

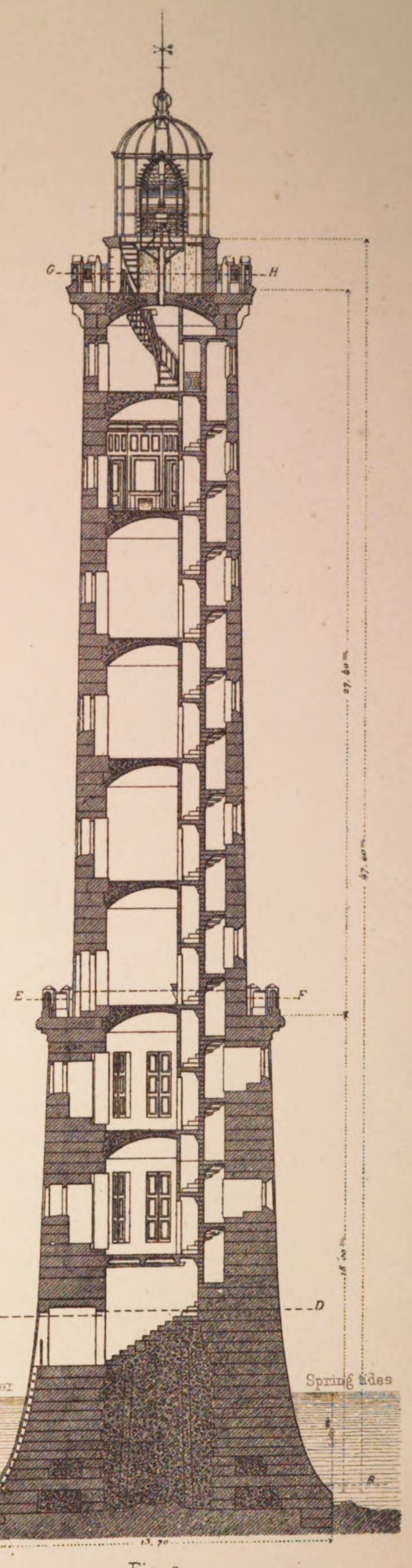



Fig. 2.

Scale of 0 1 2 3 4 5 6 7 8 9 10 meters

# LIGHT HOUSE OF BREHAT.

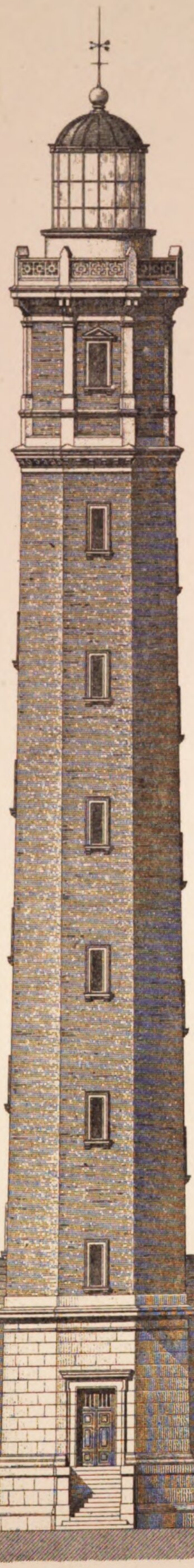


Fig. 1.

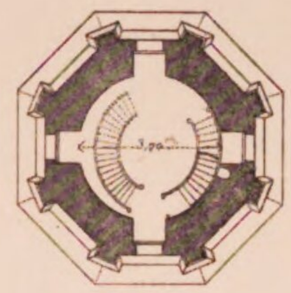


Fig. 5.

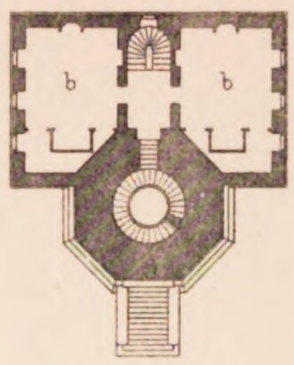


Fig. 4.

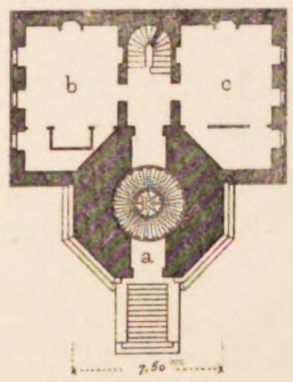


Fig. 3.

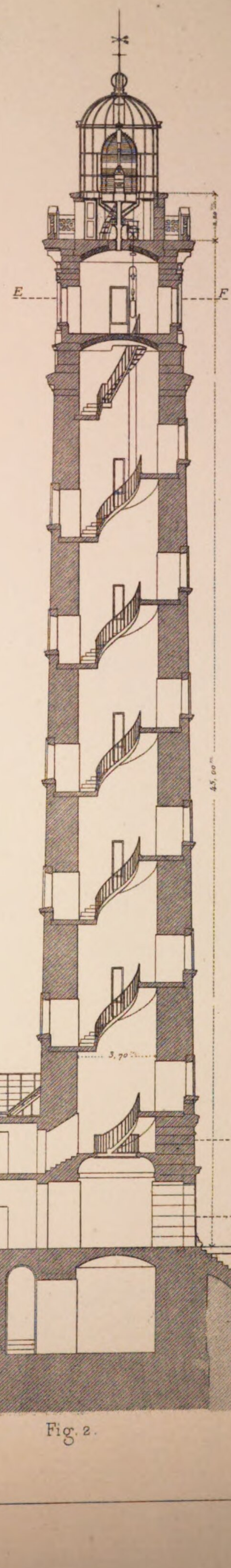


Fig. 2.

Scale for Fig.s { 1. 2 and 5 / 3 and 4 } 0 1 2 3 4 5 10 meters.

# LIGHT HOUSE OF CALAIS.

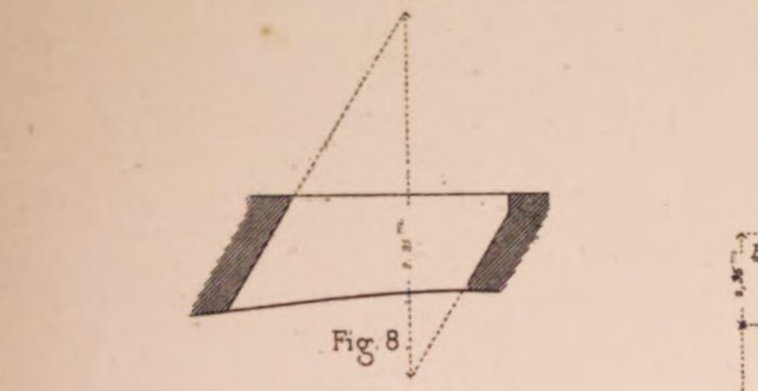


Fig. 8.

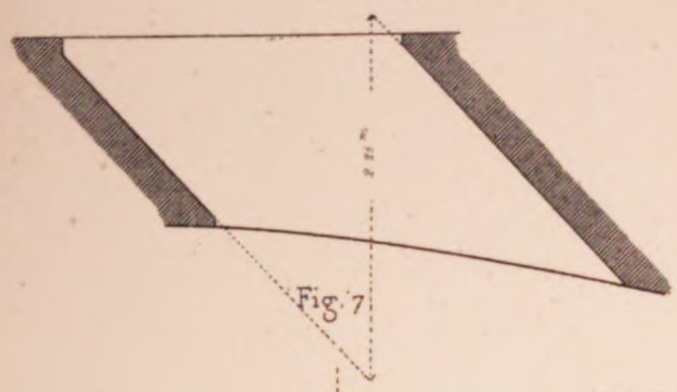


Fig. 7.

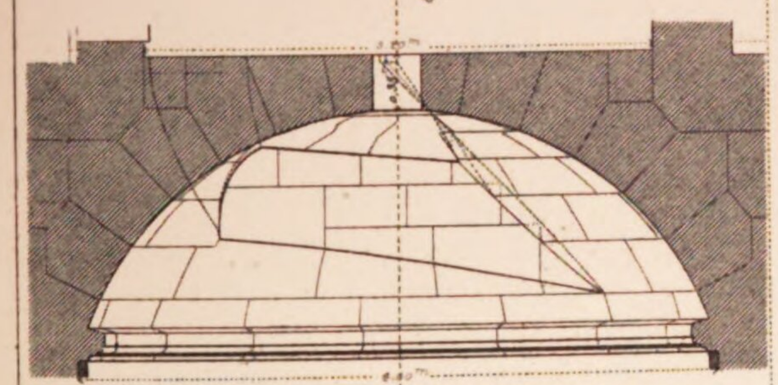


Fig. 6.

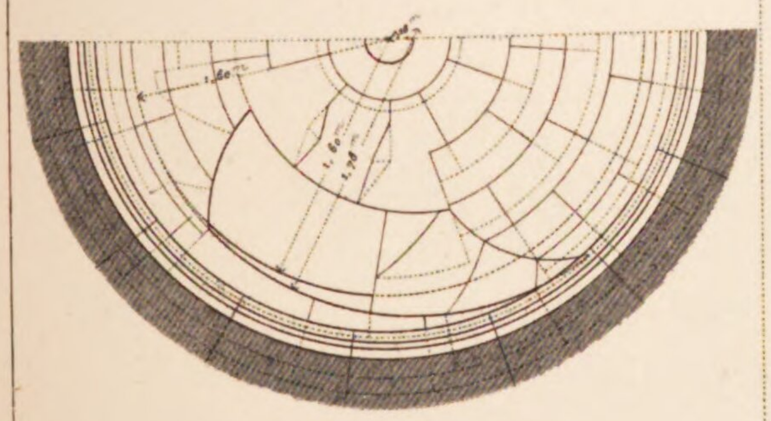


Fig. 5.

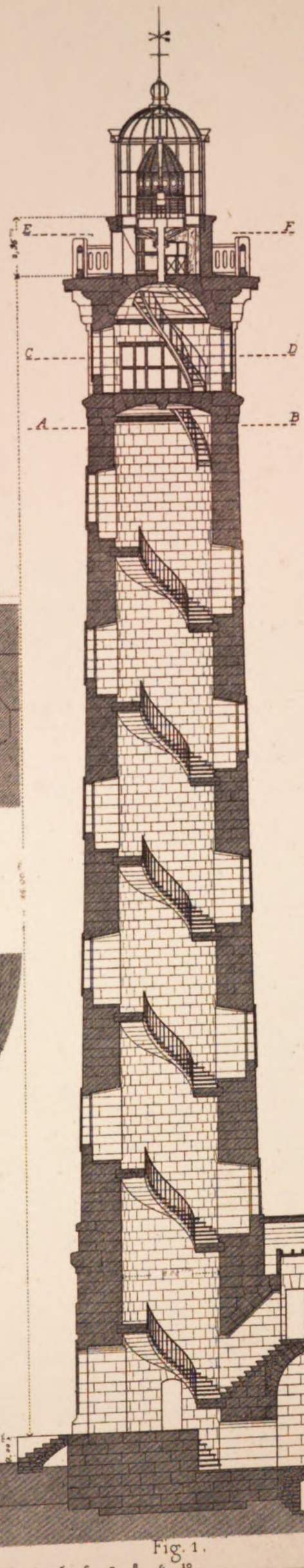



Fig. 1.

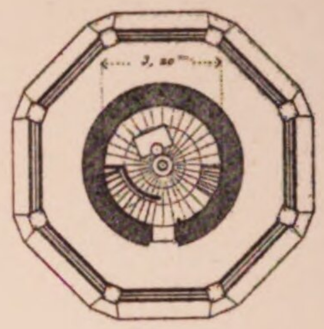


Fig. 4.

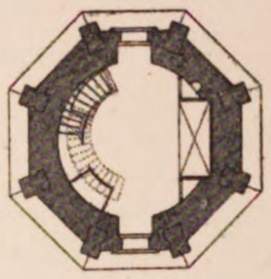


Fig. 3.

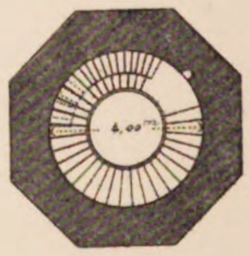
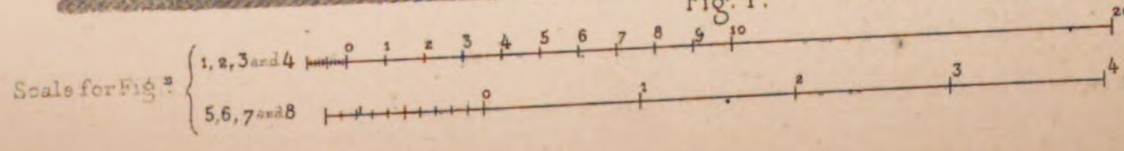


Fig. 2.




# LIGHT HOUSE OF BALEINES.

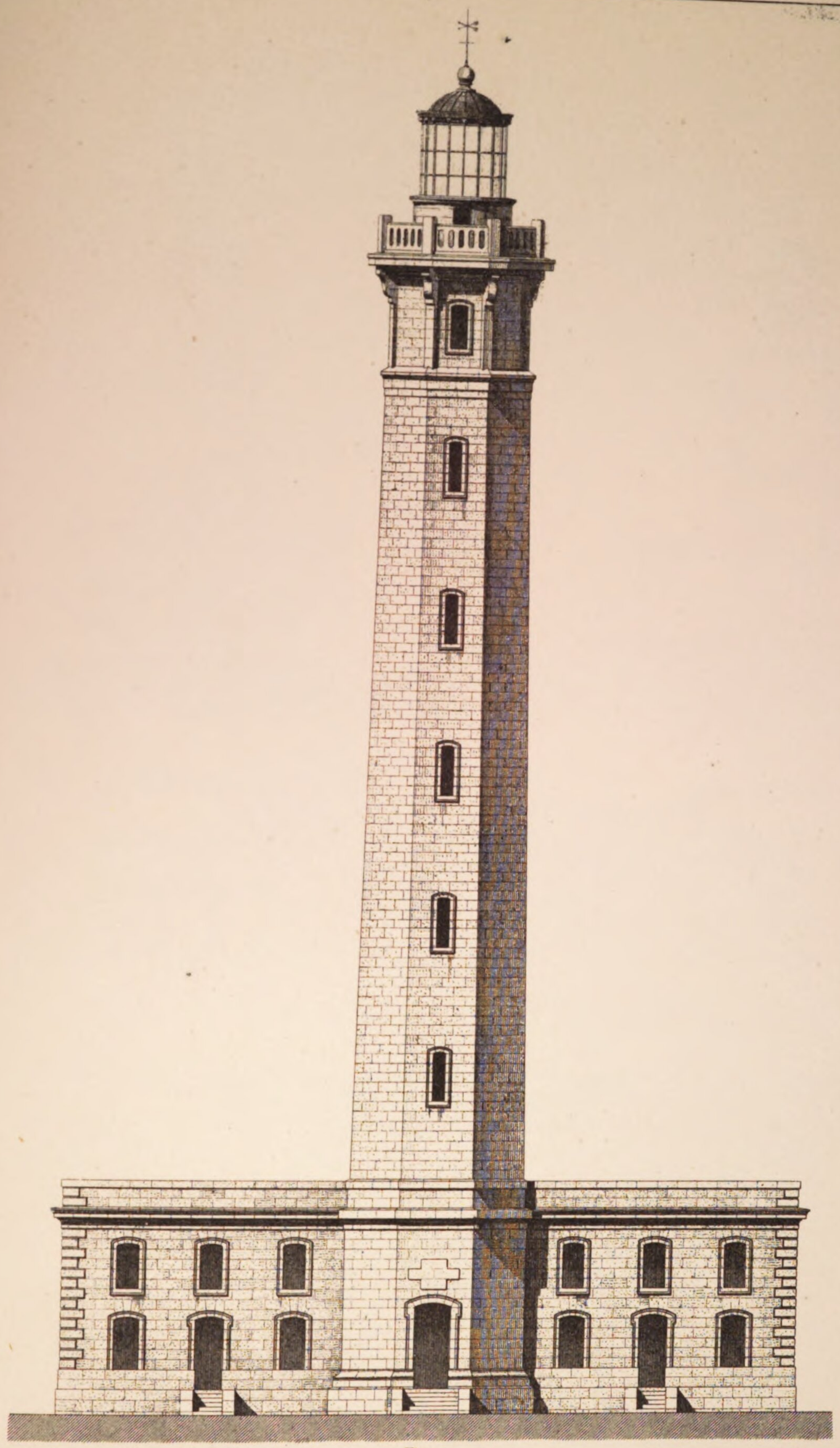


Fig. 2.




Fig. 1.

Scale for Figs 1
2
20 meters
20 meters

# LIGHT HOUSE OF BALEINES.



Fig. 1.




Fig. 2.

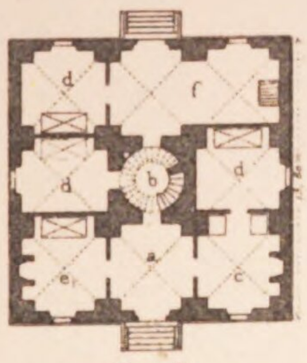



Fig. 3.

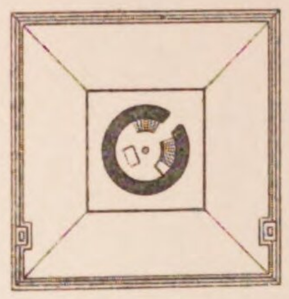


Fig. 4.

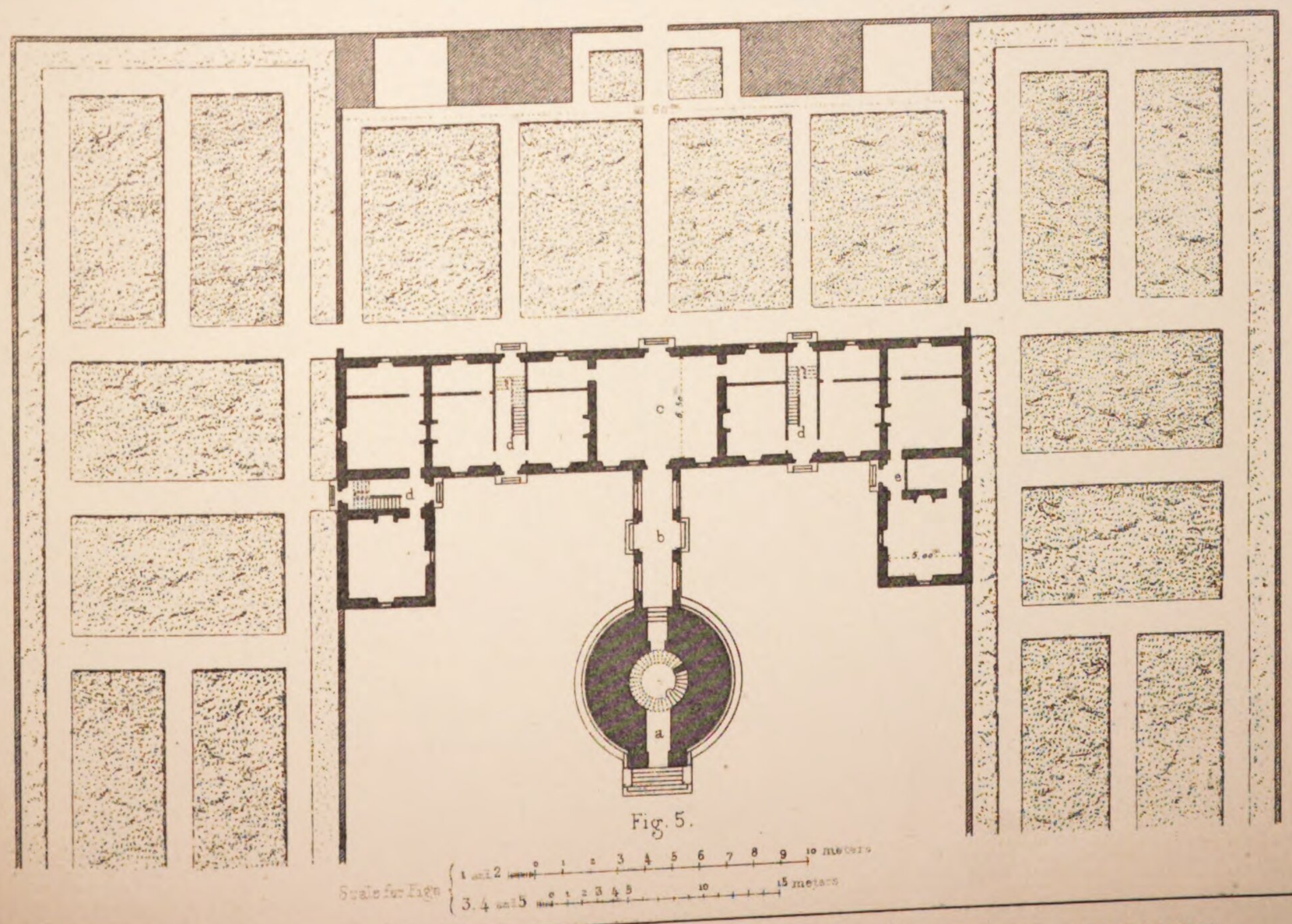



Fig. 5.

LIGHT HOUSE OF PORTO-VECCHIO

Fig. 1 to 5

LIGHT HOUSE OF OUESSANT.

Fig. 5




Fig. 1.

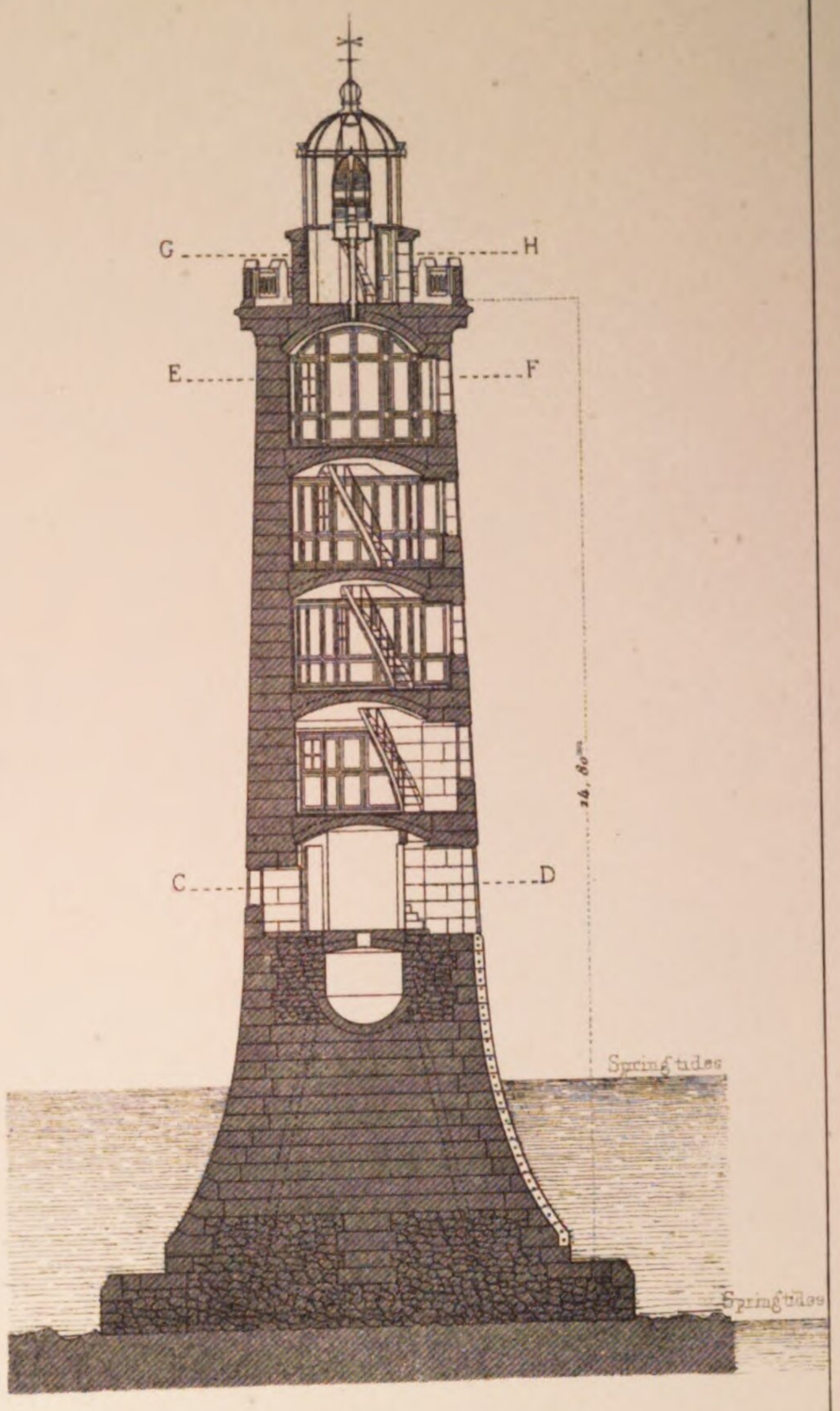



Fig. 2.



Fig. 4.

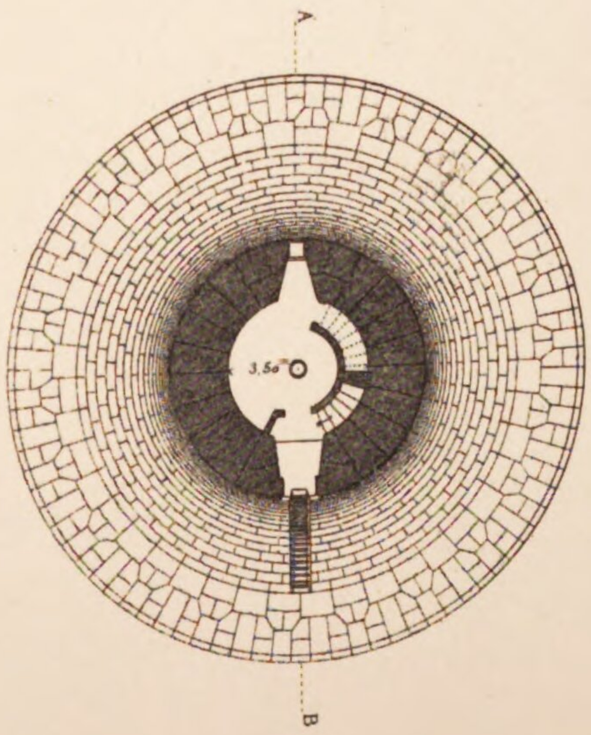



Fig. 3.

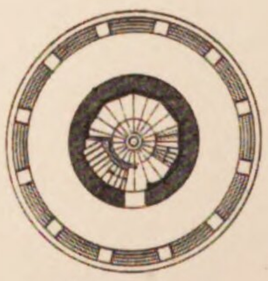
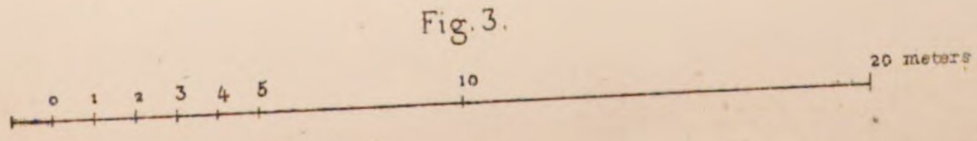


Fig. 5.




LIGHT HOUSE OF HAUT-BANC DU NORD.

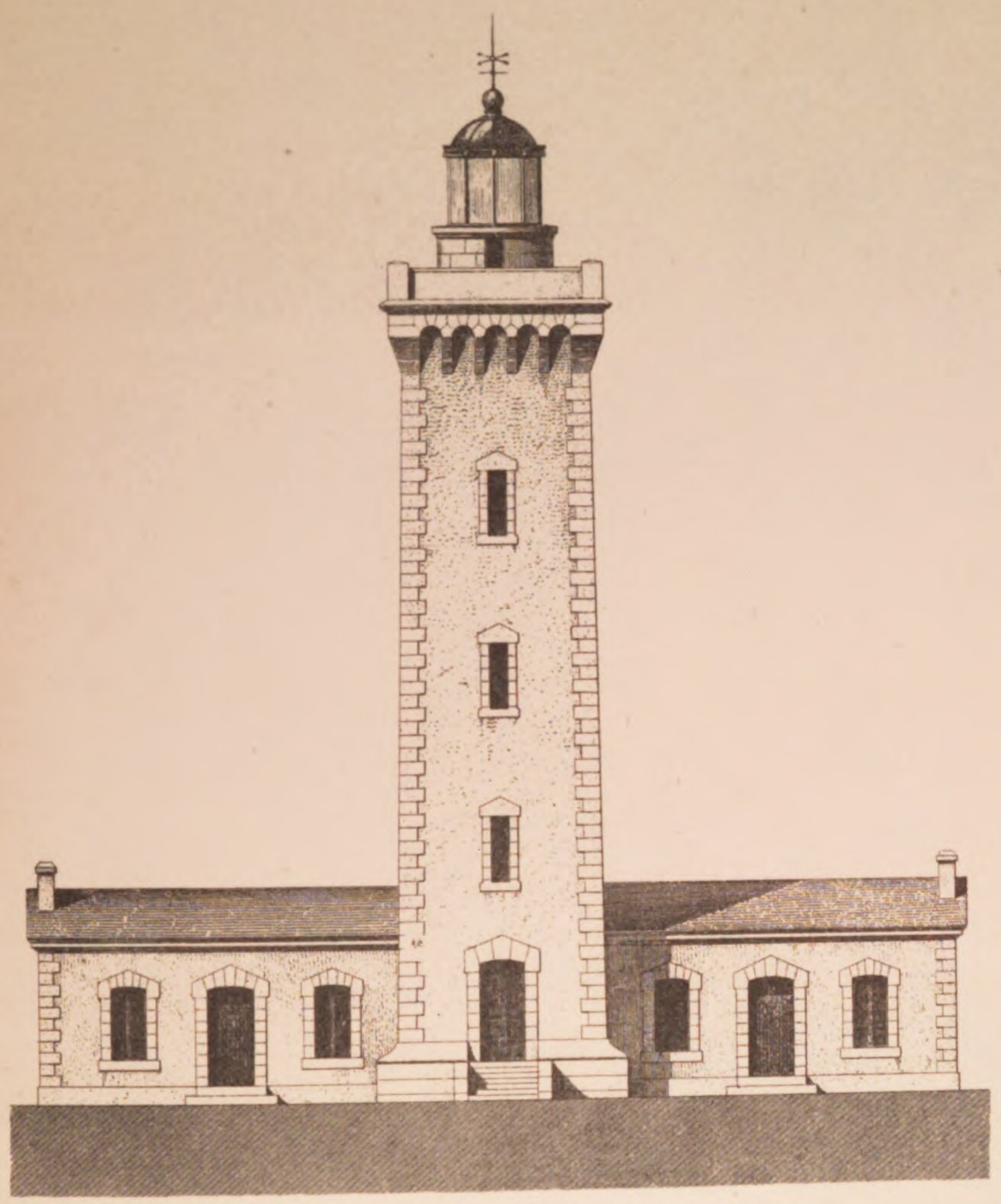


Fig. 1.

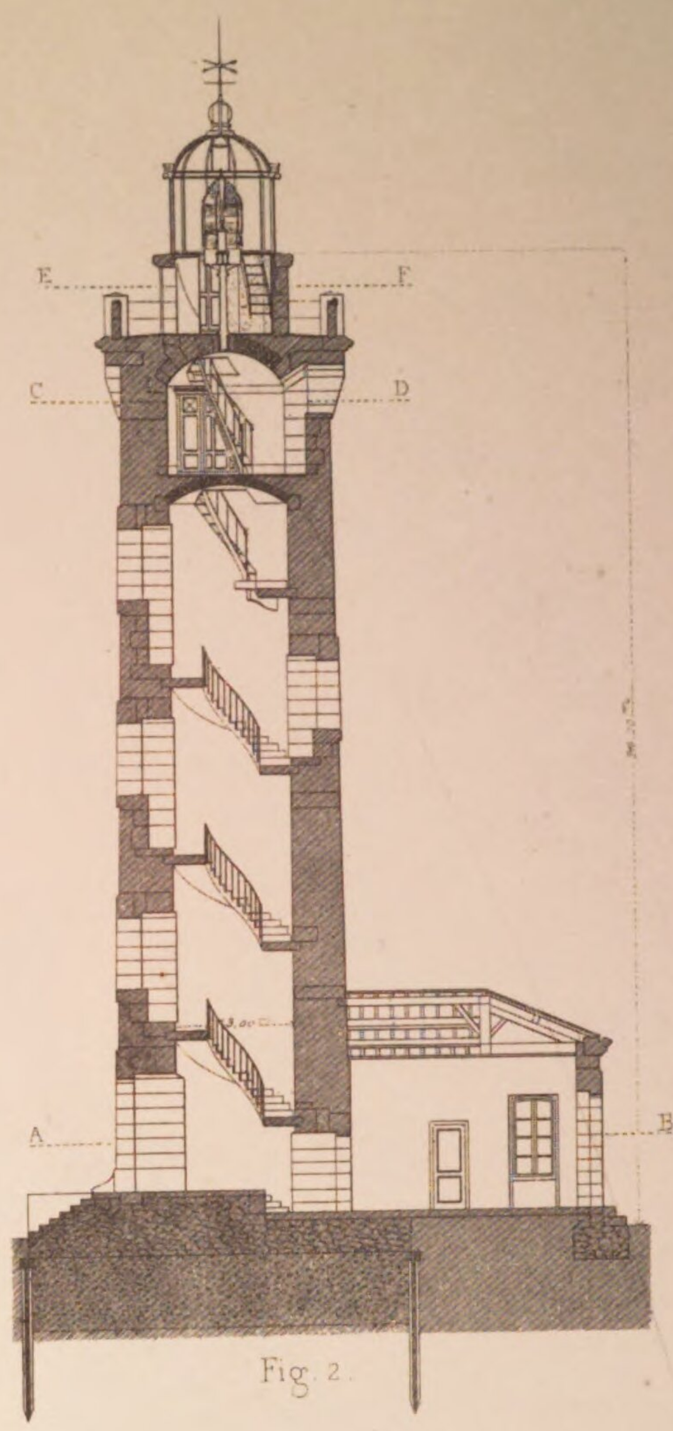



Fig. 2.



Fig. 4.

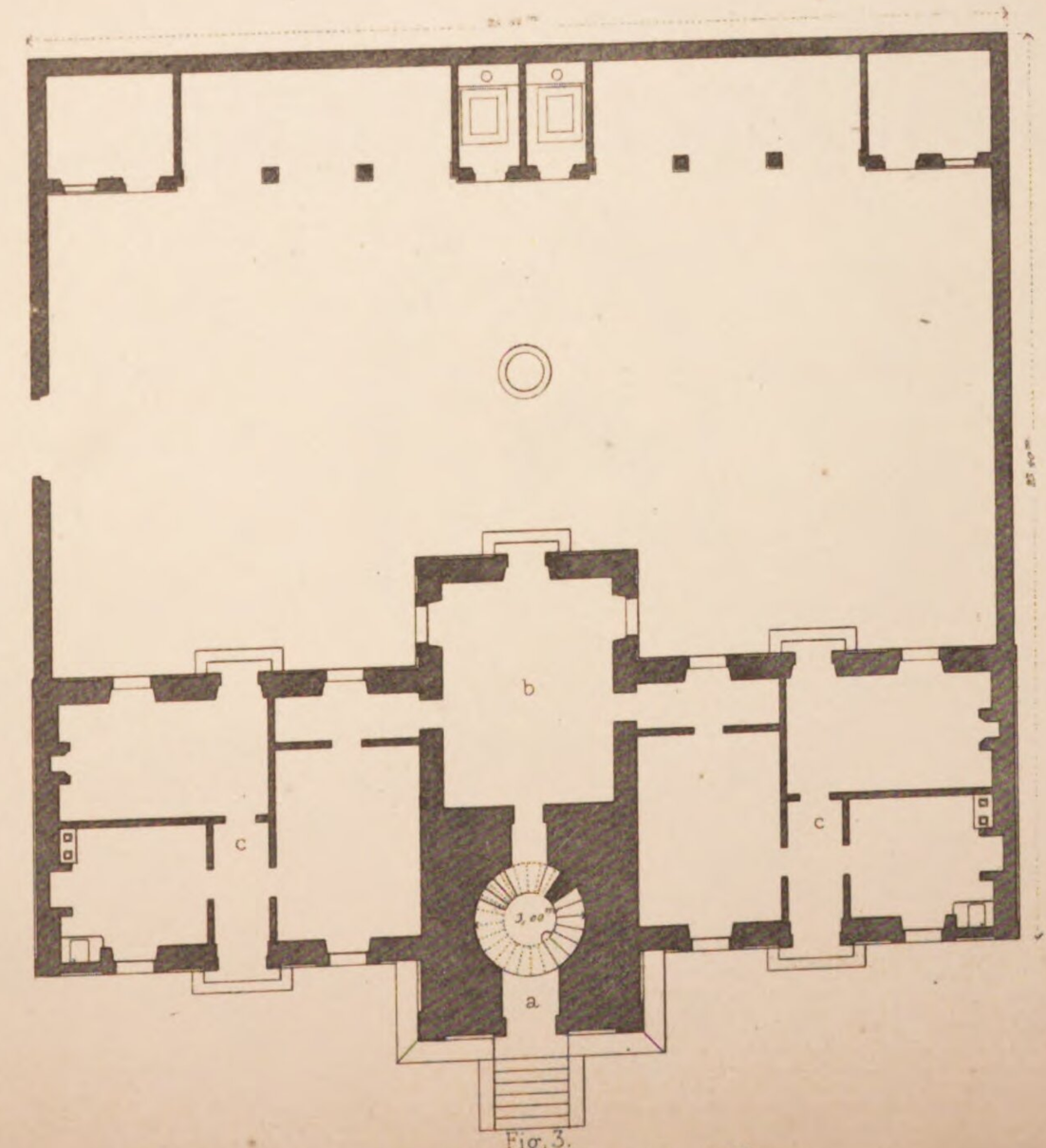



Fig. 3.

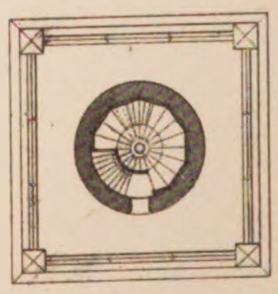


Fig. 5.

Scale of 0 1 2 3 4 5 6 7 8 9 10 meters

# LIGHT HOUSE OF GRAVE.




Fig. 1.

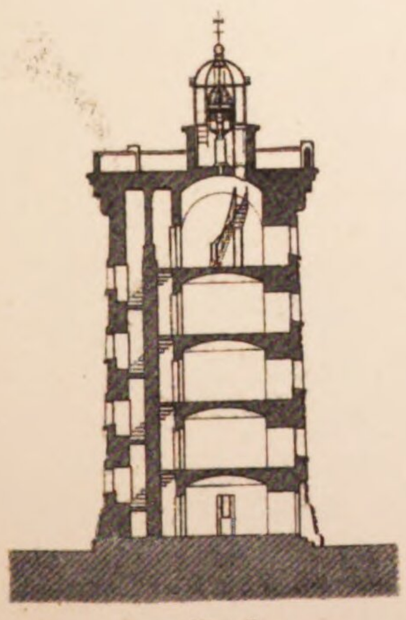


Fig. 3.

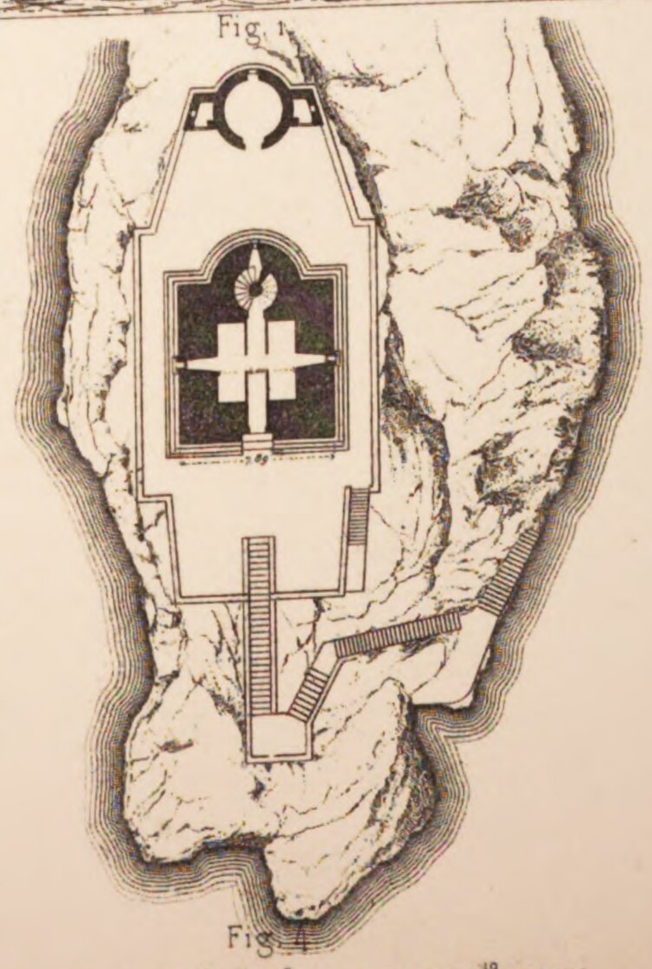


Fig. 4

Scale for Fig.s 1, 3 & 4 — 0 1 2 3 4 5 10 meters; 0 10 20 meters

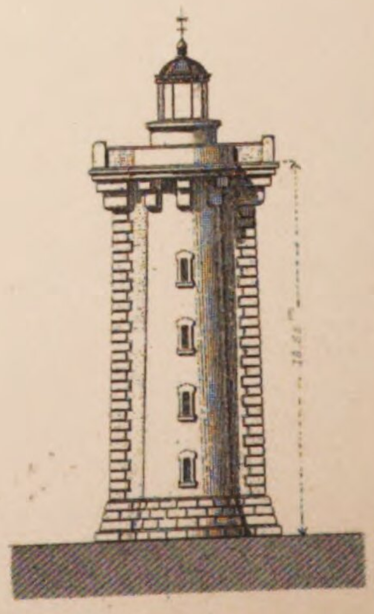


Fig. 2

# LIGHT HOUSE OF TRIAGOZ.

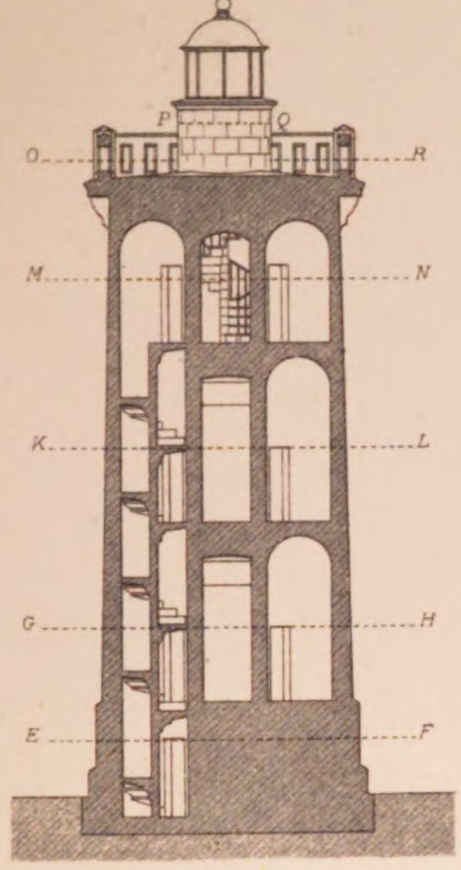



Fig. 2.



Fig. 1.

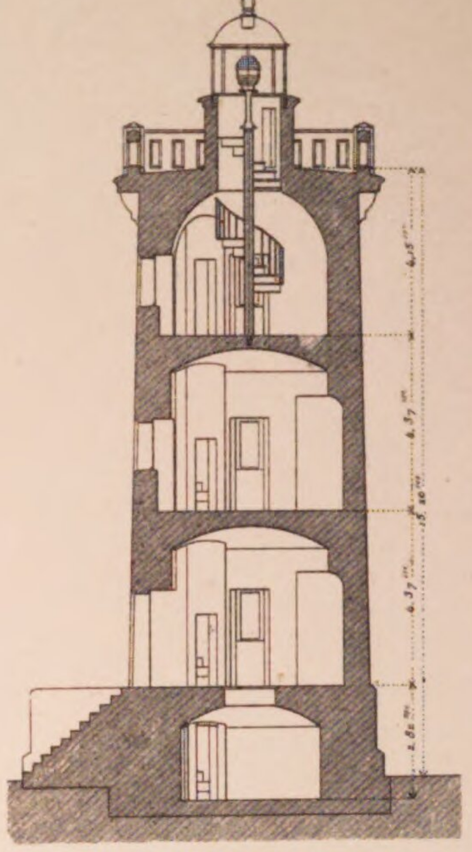


Fig. 3.

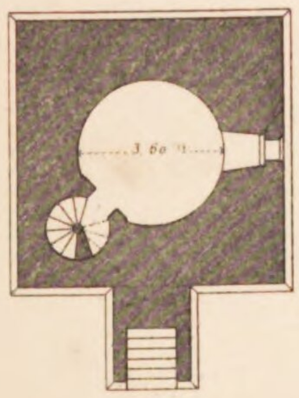



Fig. 4.

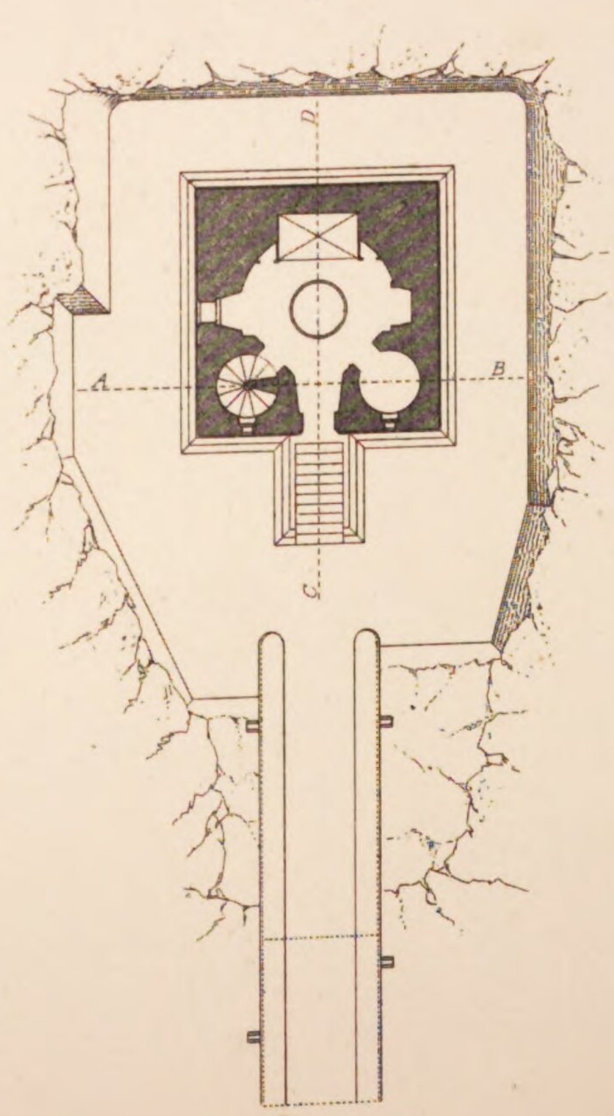



Fig. 5.

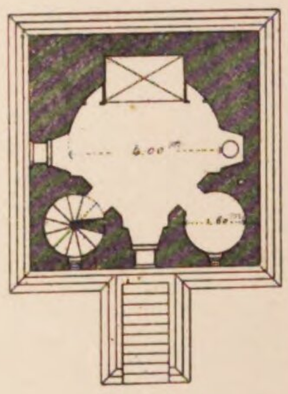



Fig. 6.

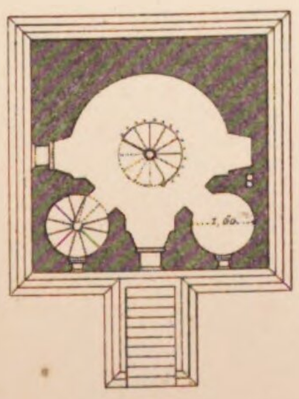



Fig. 7.

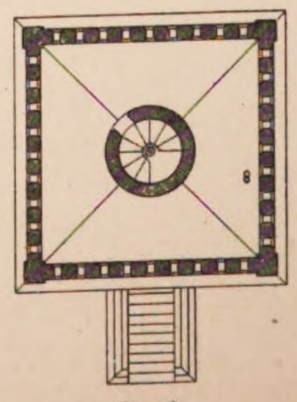


Fig. 8.

Scale of 0 1 2 3 4 5 6 7 8 9 10 meters

# LIGHT HOUSE OF KERMORVAN.

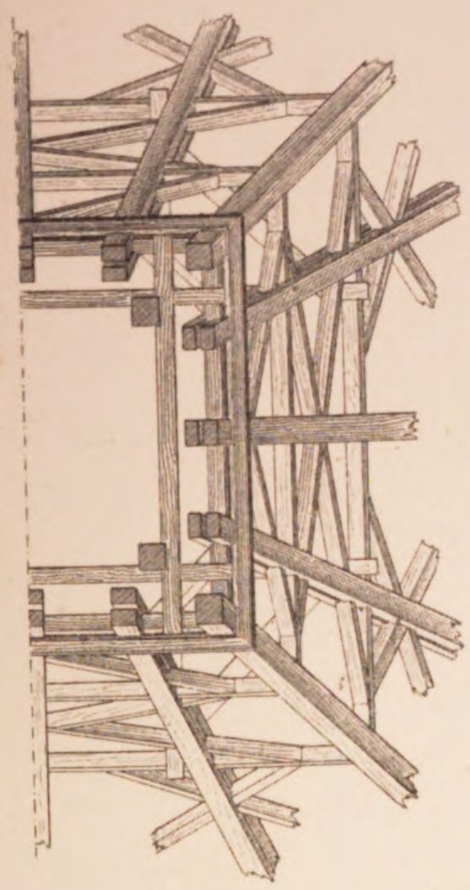


Fig. 4.

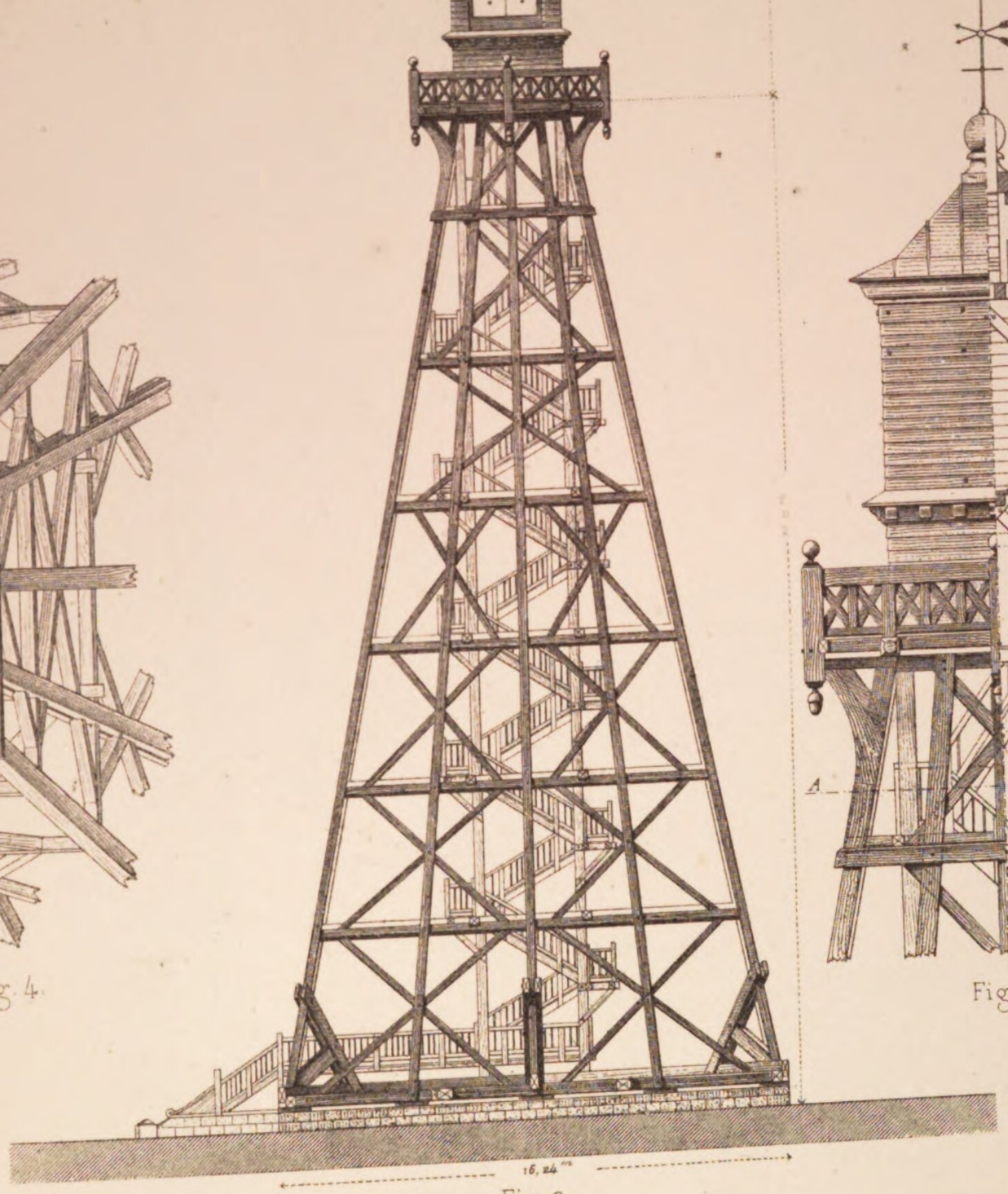



Fig. 2.




Fig. 3.

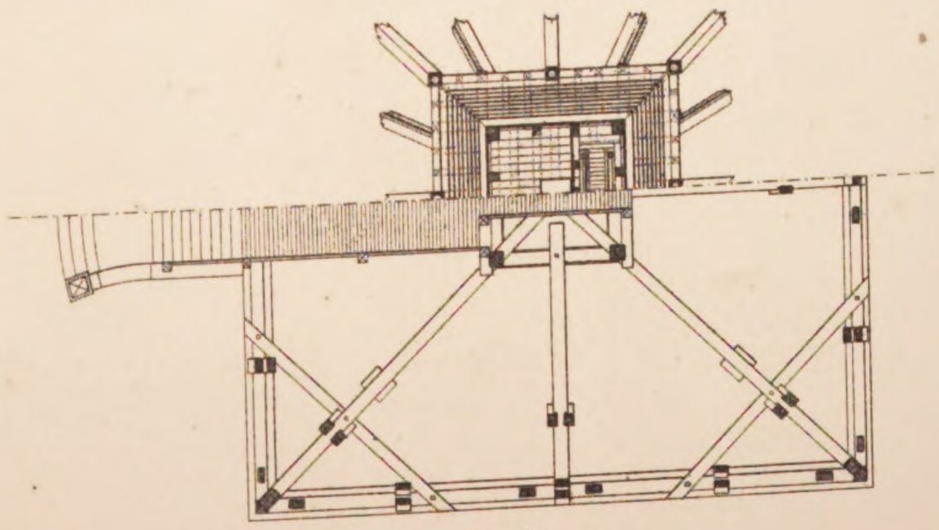
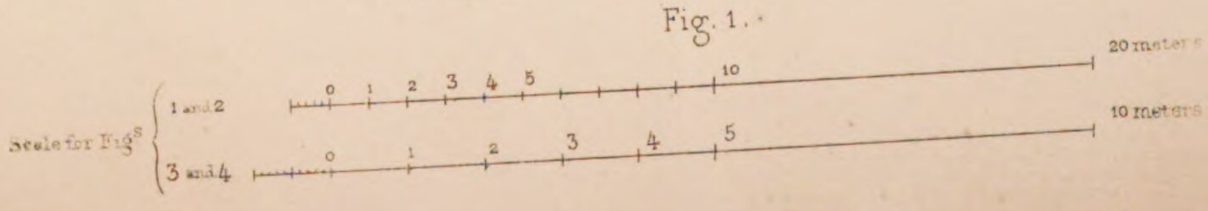


Fig. 1.




# LIGHT HOUSE OF PONTAILLAC.

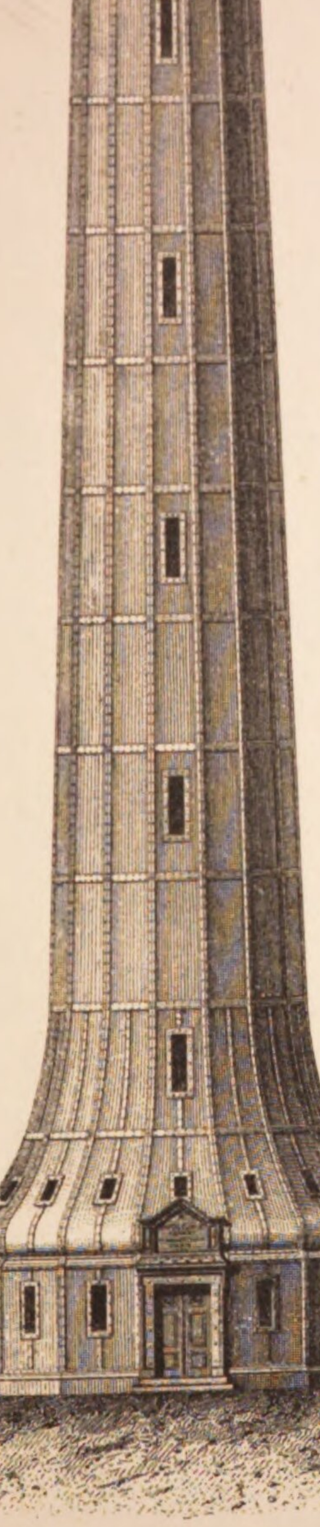


Fig. 1.

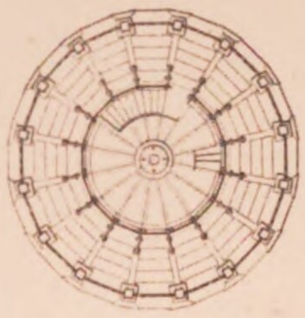


Fig. 5.

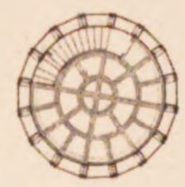


Fig. 4.

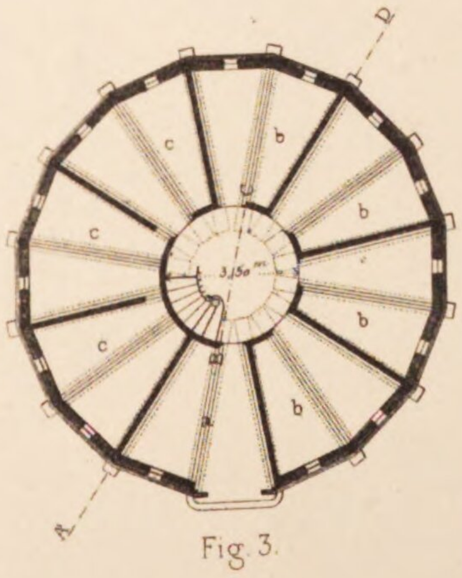



Fig. 3.

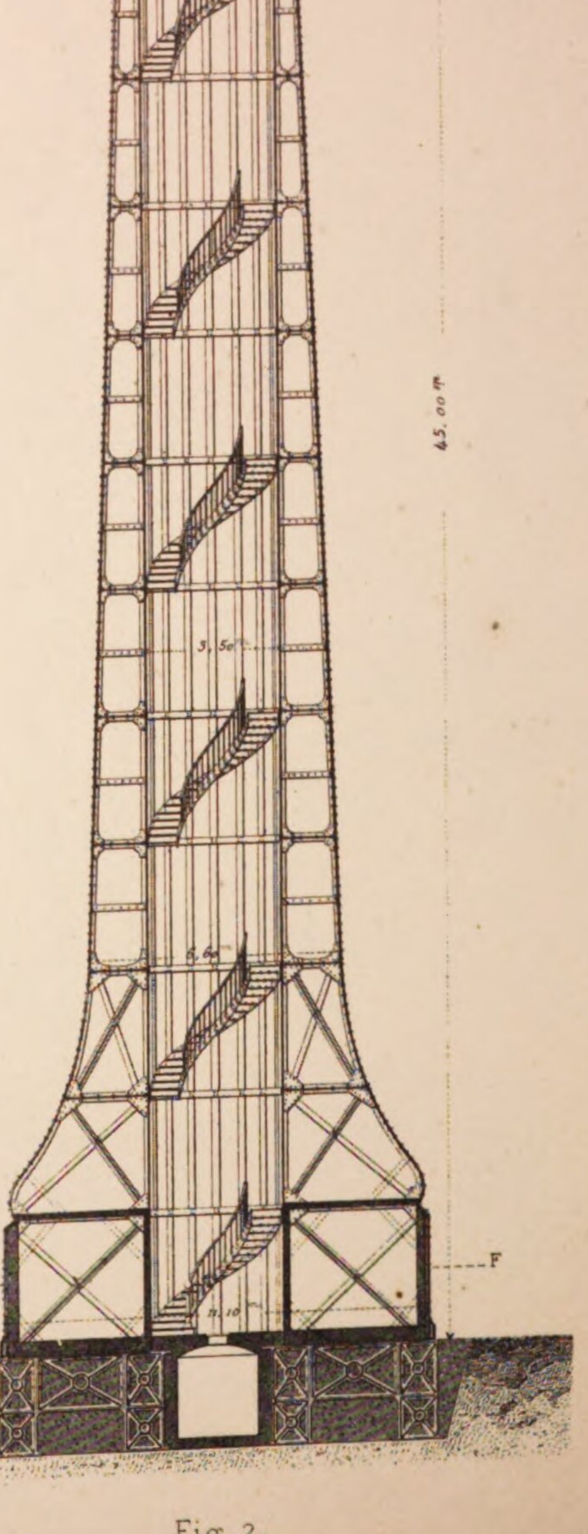



Fig. 2.

Scale of 0 1 2 3 4 5 10 meters.

# LIGHT HOUSE OF NEW CALEDONIA

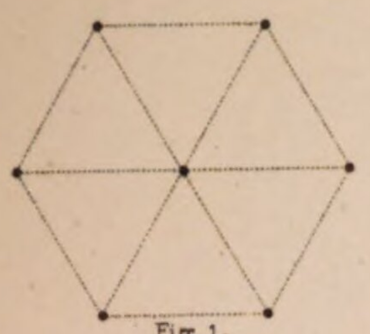


Fig. 1.

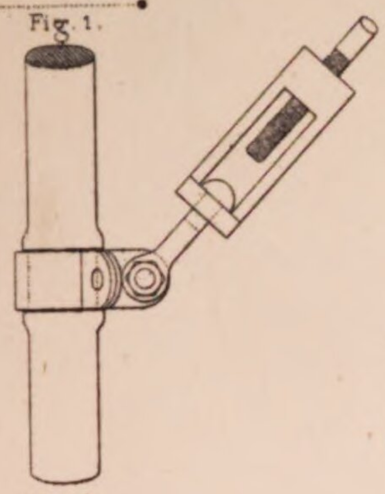


Fig. 8.

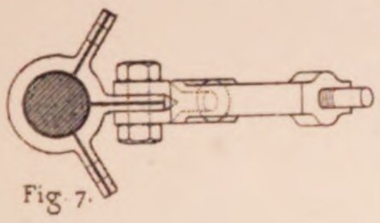


Fig. 7.

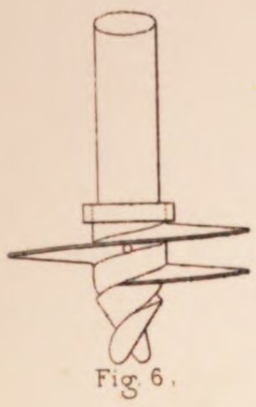


Fig 6.



Fig. 4.

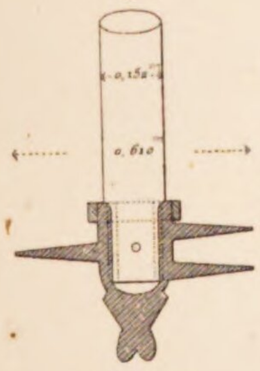


Fig. 5.

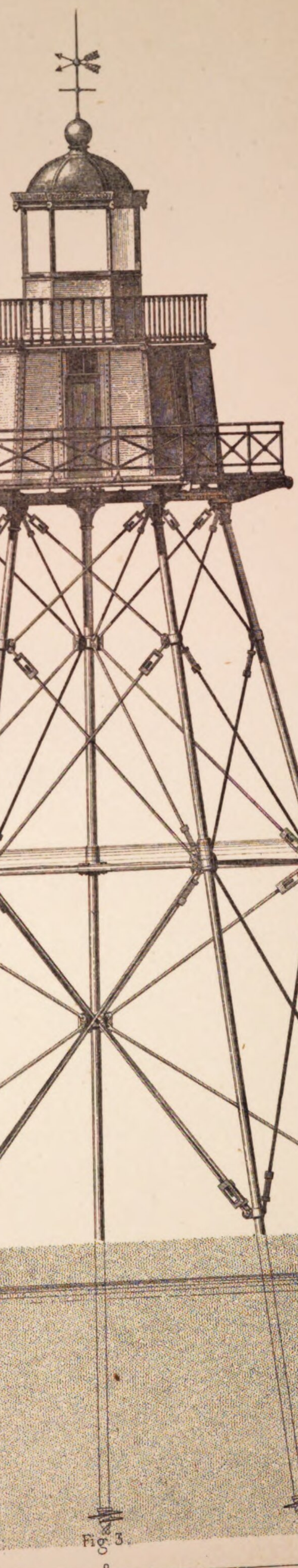



Fig. 3.

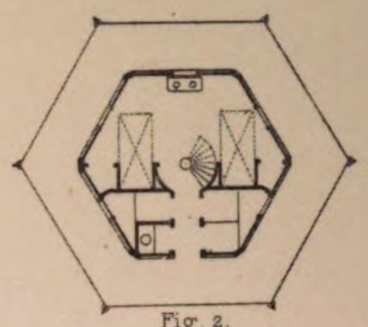


Fig. 2.

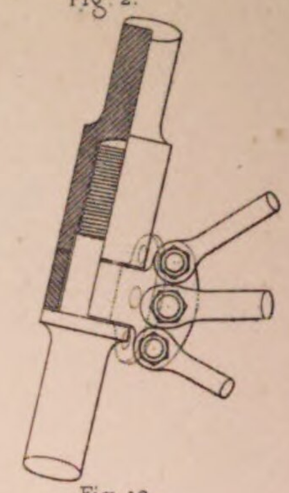


Fig. 12.

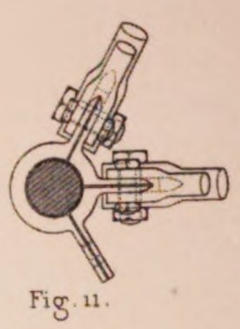


Fig. 11.



Fig. 10.



Fig 9

Scale { of Details / of Elevation } 0 1 2 3 4 5 6 7 8 9 10 meters.

# LIGHT HOUSE OF WALDE



Fig. 5.

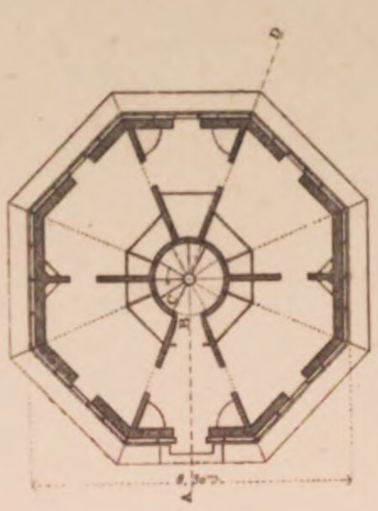


Fig. 7.

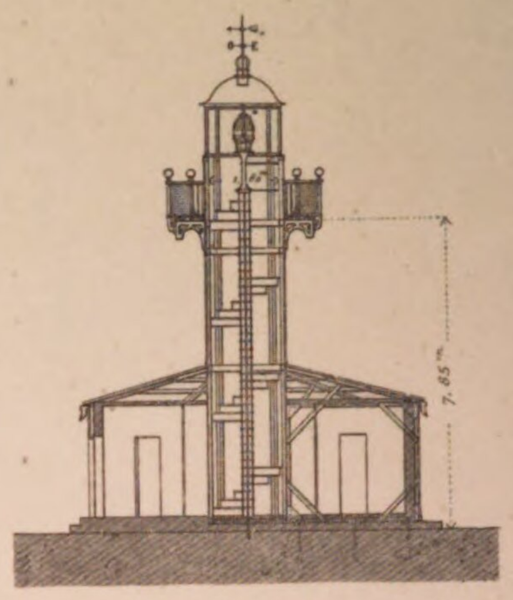


Fig. 6.

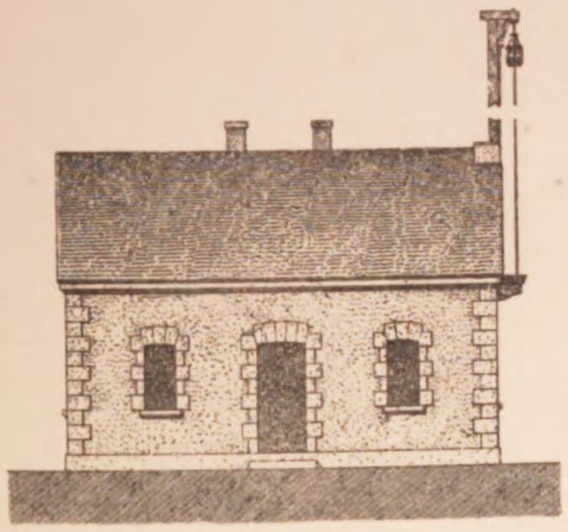


Fig. 8.

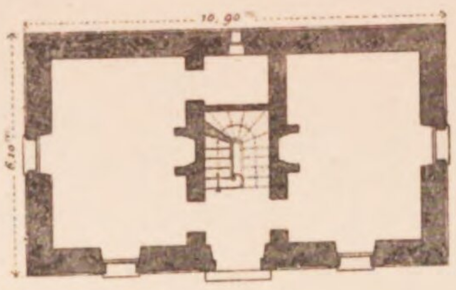


Fig. 10.

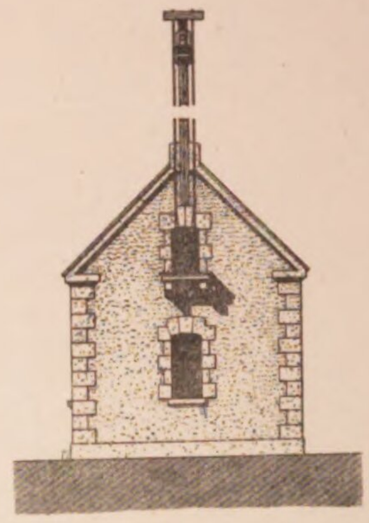


Fig. 9

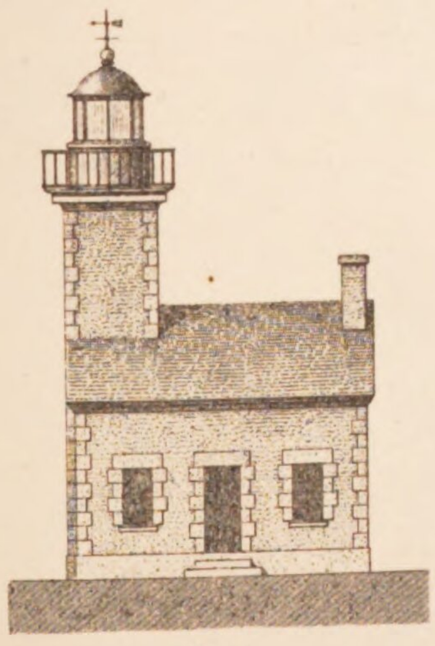


Fig. 1.

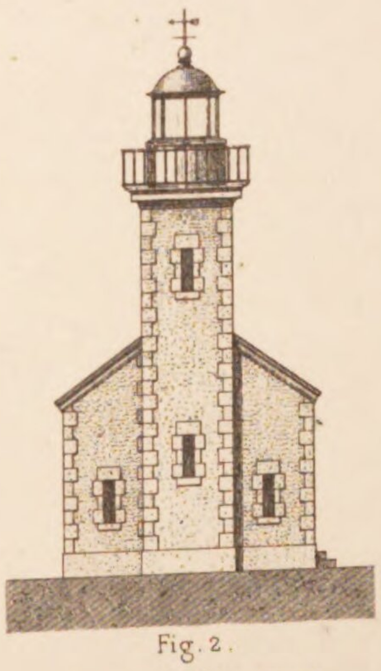


Fig. 2.

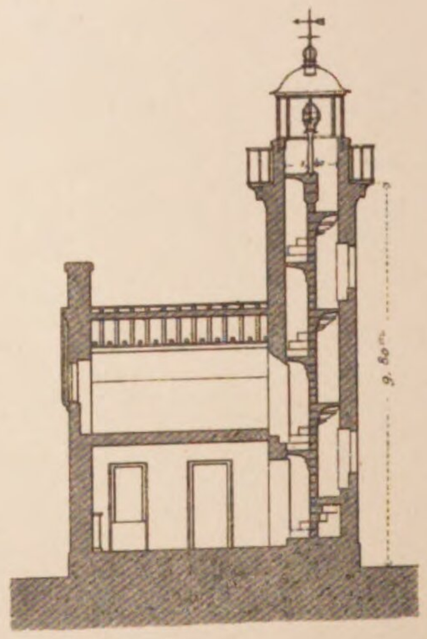


Fig. 3.

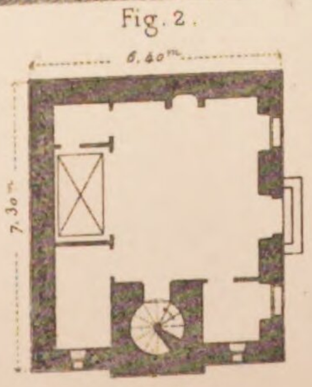


Fig. 4.

Scale of 0 1 2 3 4 5 10 15 meters

HARBOR LIGHTS WITH DWELLINGS.

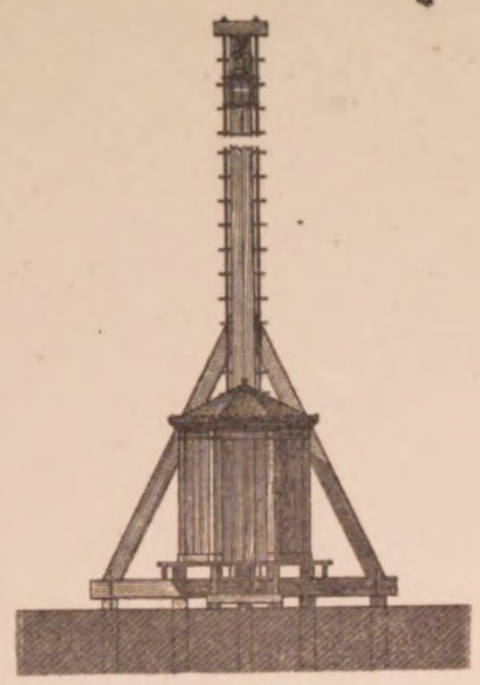


Fig. 9.

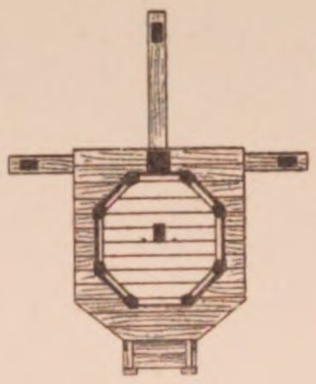


Fig. 11.

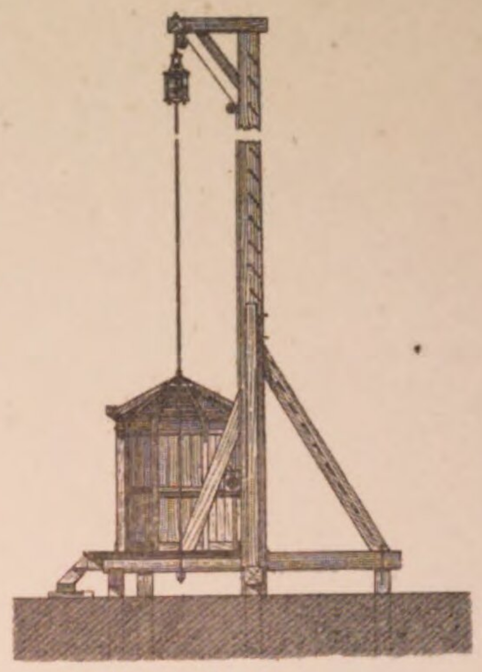


Fig. 10.

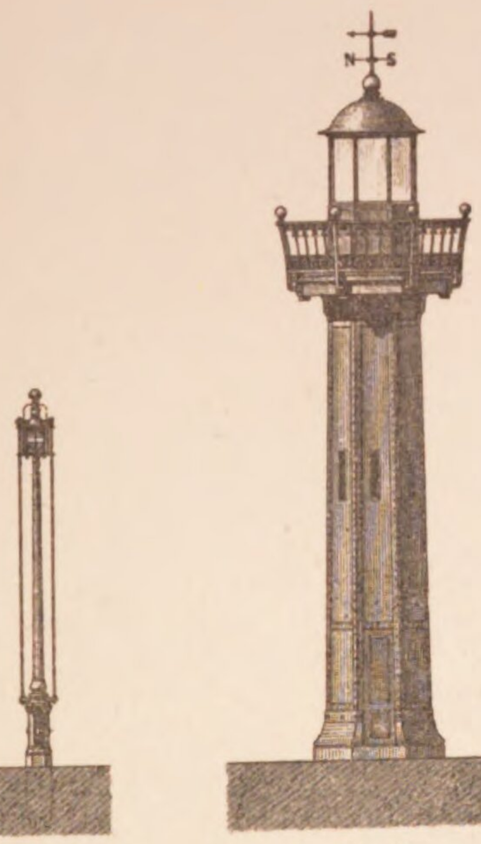


Fig. 14.



Fig. 5.



Fig. 8.



Fig. 7.

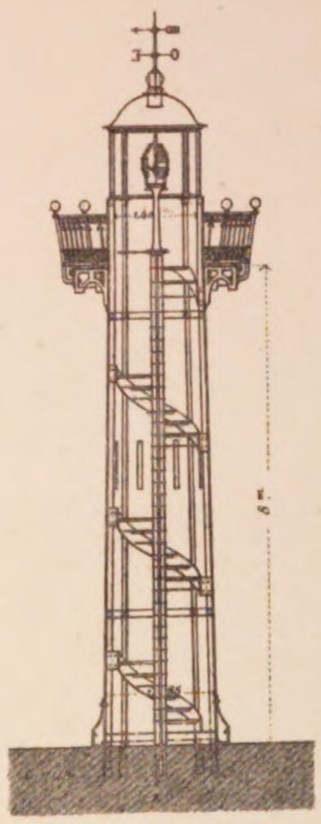


Fig. 6.

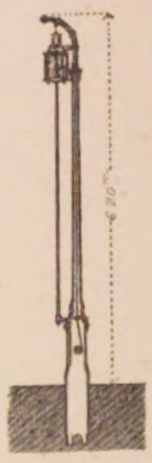


Fig. 15.



Fig. 12.

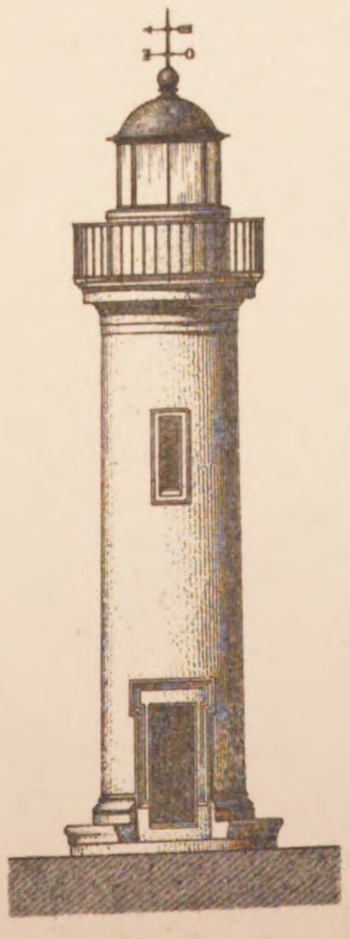


Fig. 1.



Fig. 4.



Fig. 3.

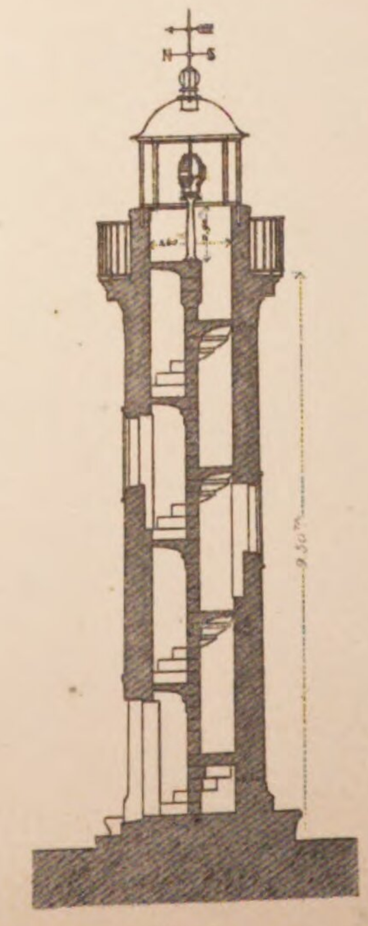


Fig. 2.

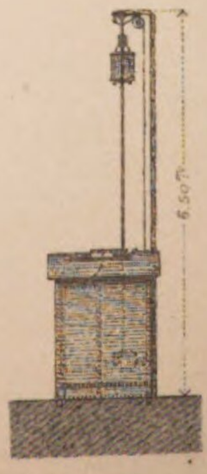


Fig. 13.

Scale of 0 1 2 3 4 5 10 meters

HARBOR LIGHTS

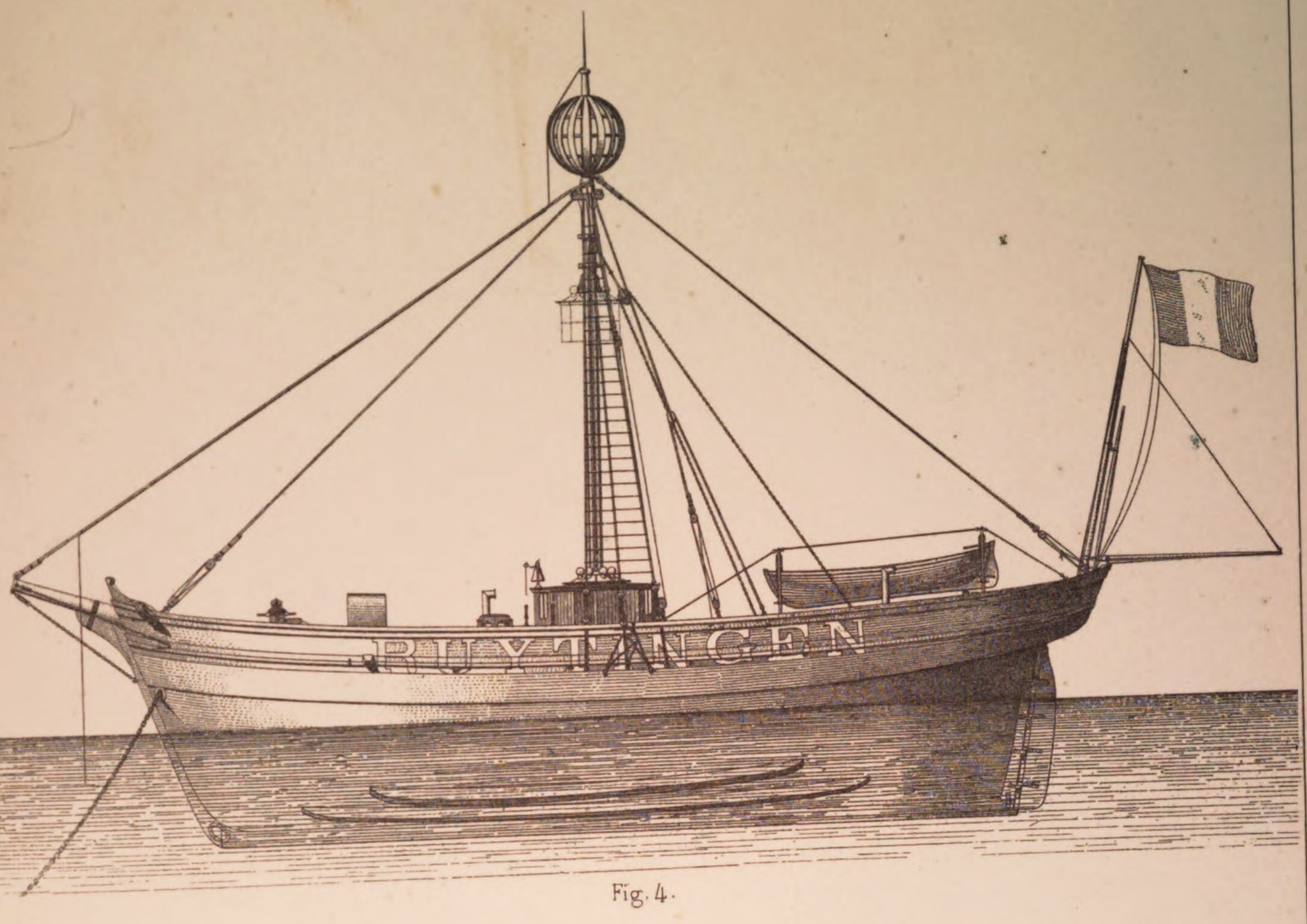



Fig. 4.

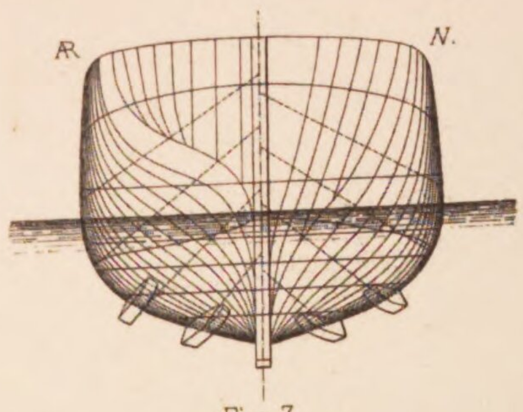



Fig. 3.

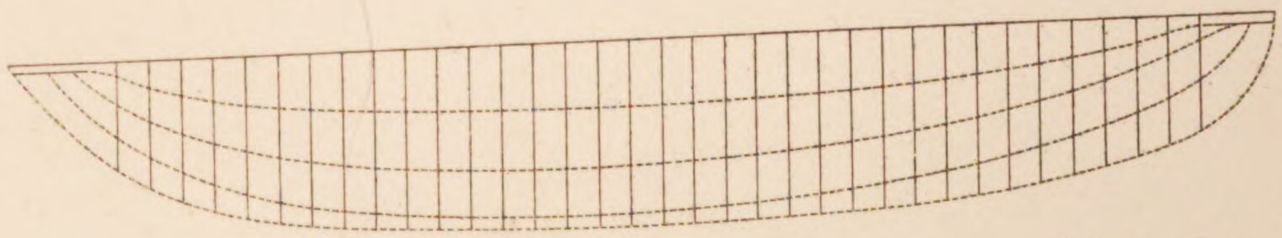


Fig. 2.

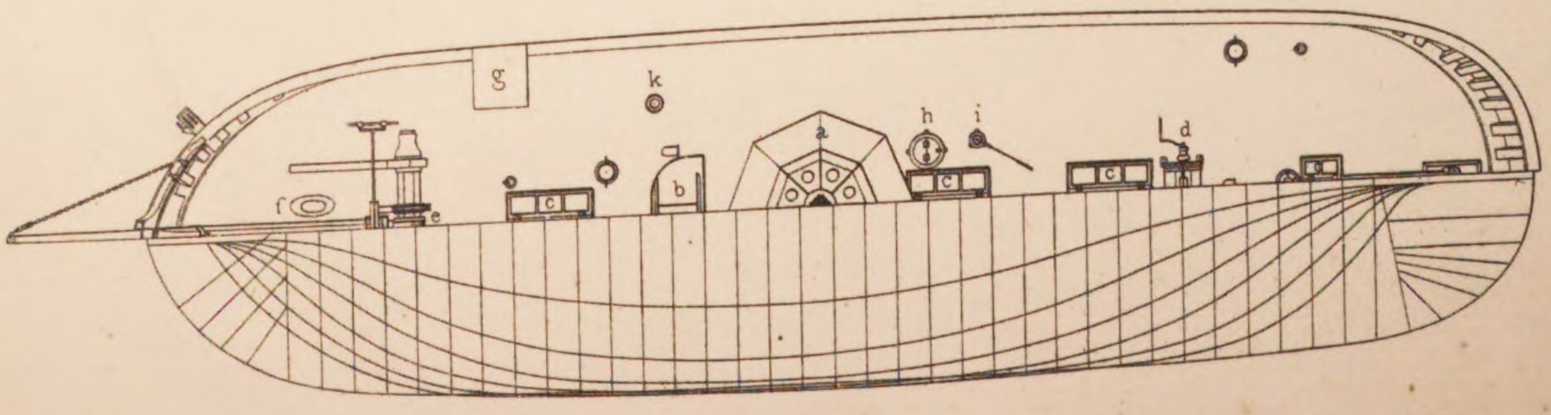



Fig. 1.

# LIGHT SHIP OF RUYTINGEN.

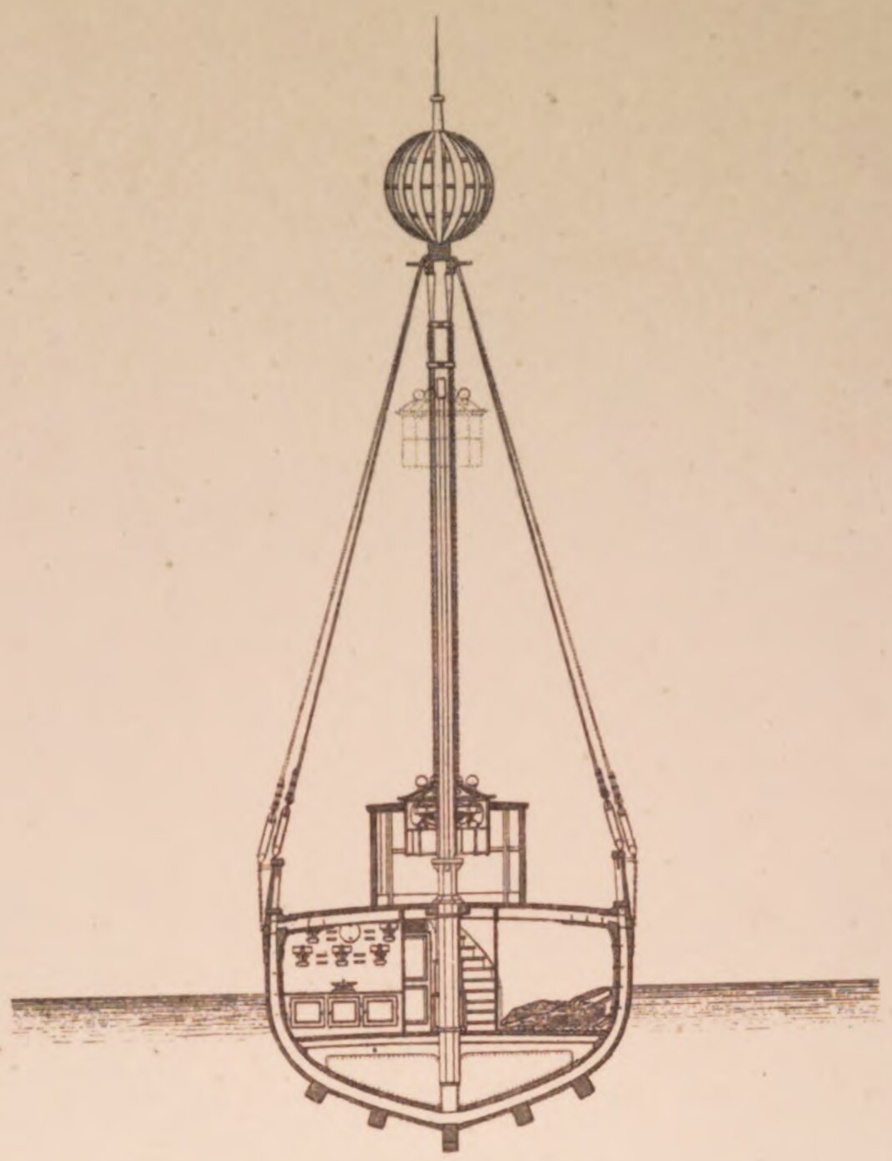


Fig. 3.

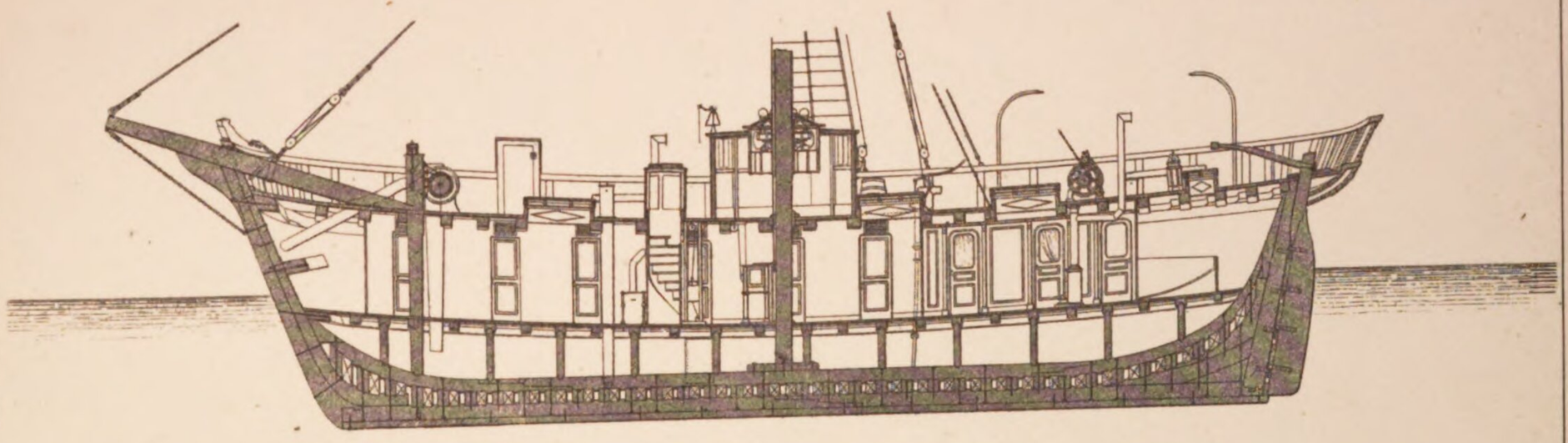


Fig. 2.

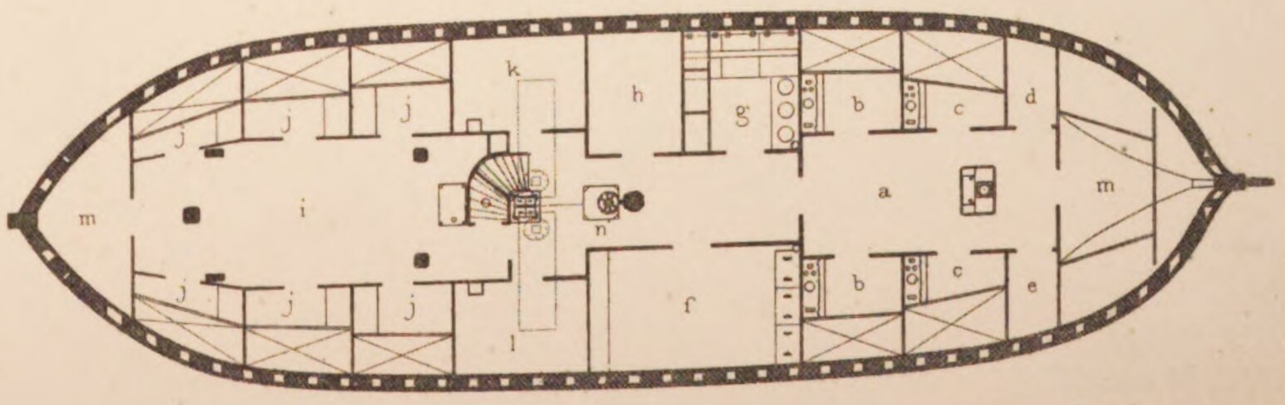
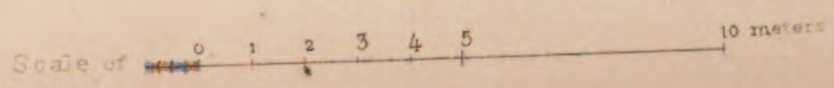



Fig. 1.




# LIGHT SHIP OF RUYTINGEN.

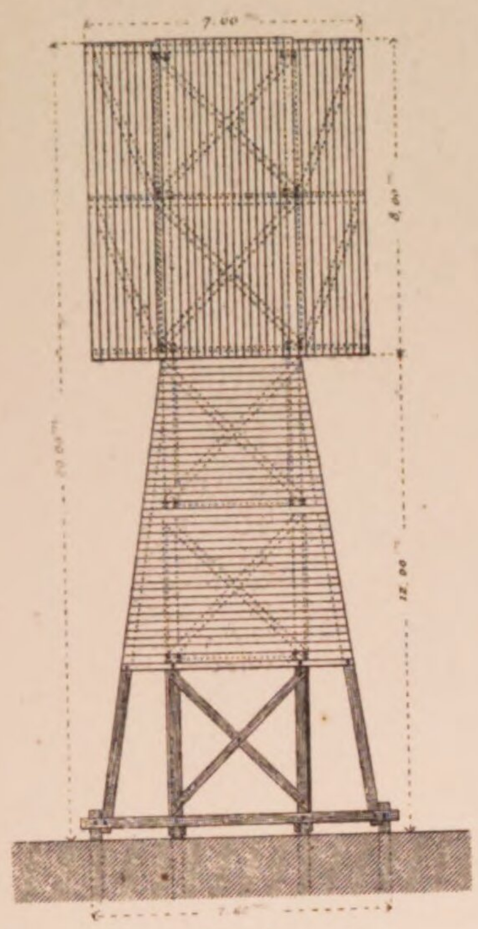


Fig. 4.

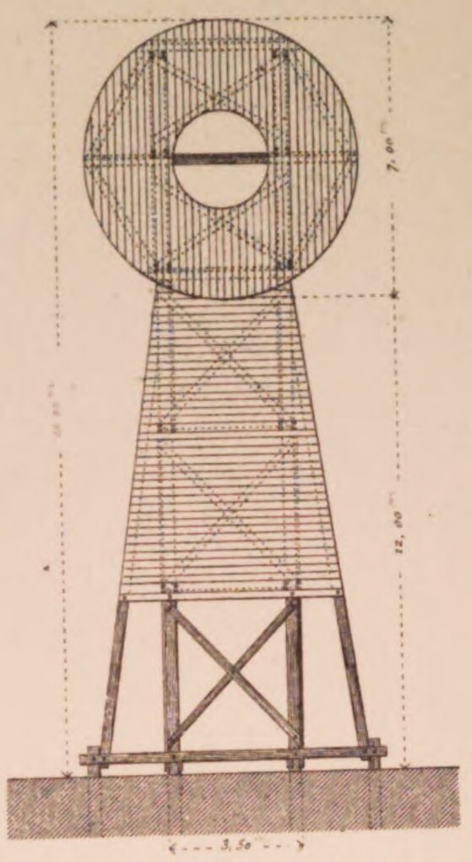


Fig. 2.

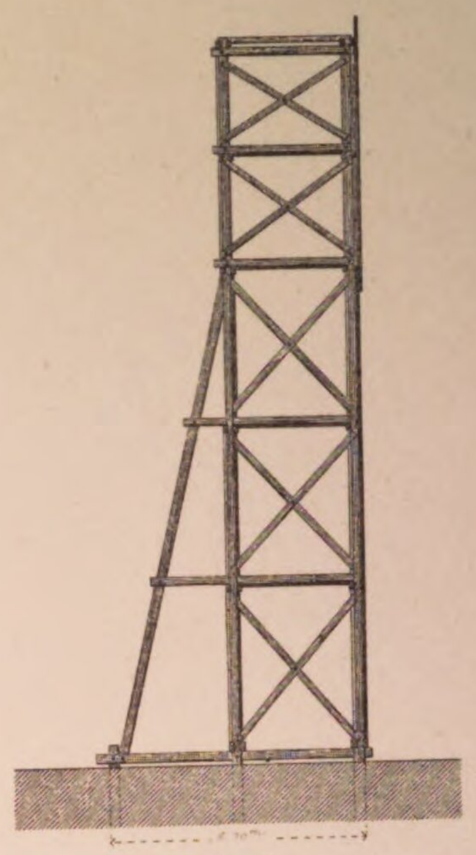


Fig. 3.

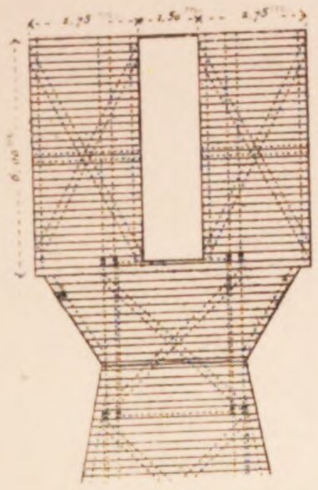


Fig. 5.

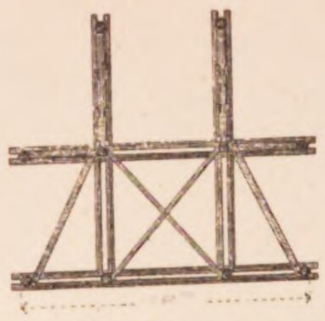


Fig. 1.

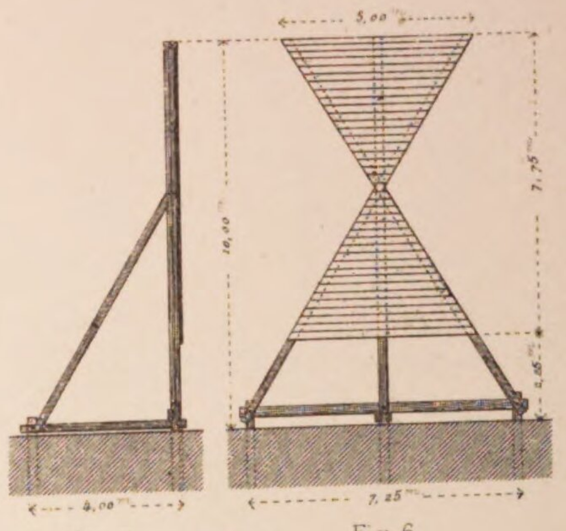


Fig. 7.

Fig. 6.

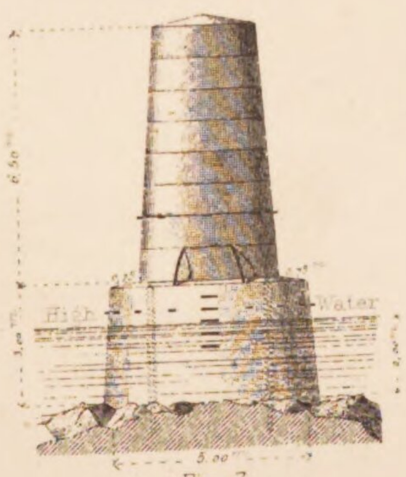
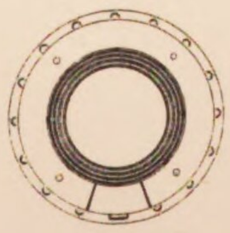


Fig. 13.



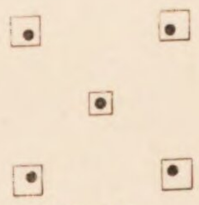


Fig. 8.

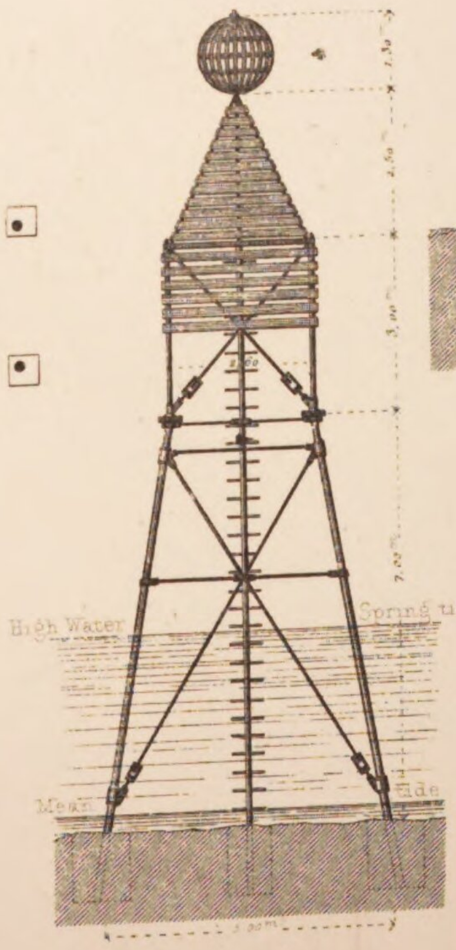



Fig. 9.

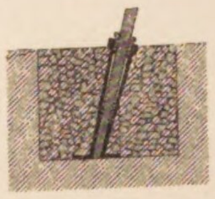


Fig. 10.




Fig. 11.

Scale for Figs. { 1 to 7 and 11 to 13. 0 1 2 3 4 5 10 20 meters
9 0 1 2 3 4 5 10 15 meters

# DAY-BEACONS.

*

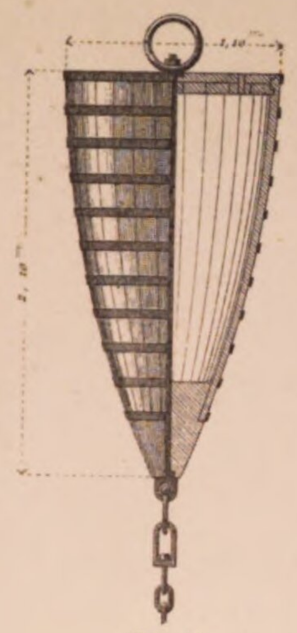


Fig. 5.

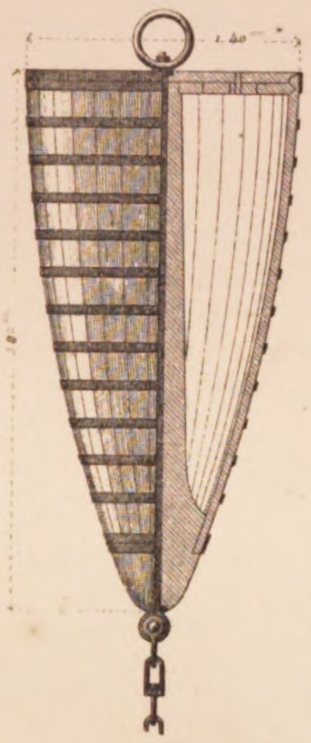


Fig. 3.

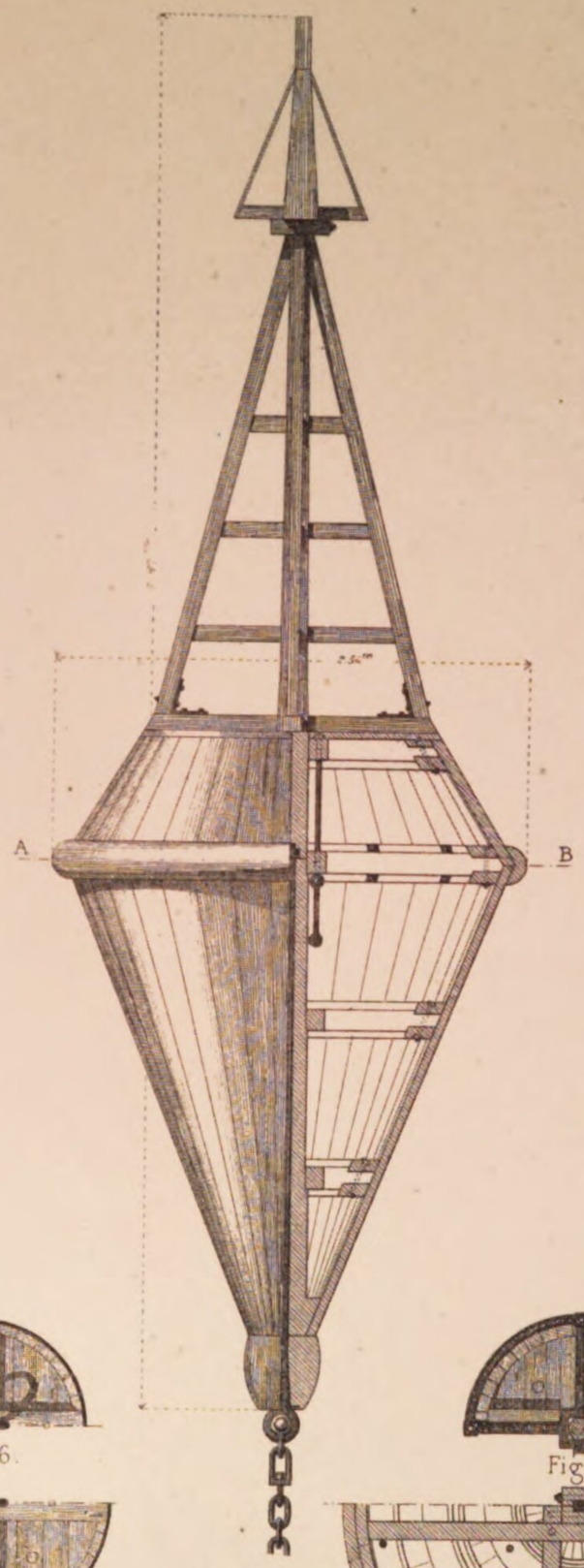



Fig. 1.



Fig. 6.



Fig. 4.



Fig. 8.

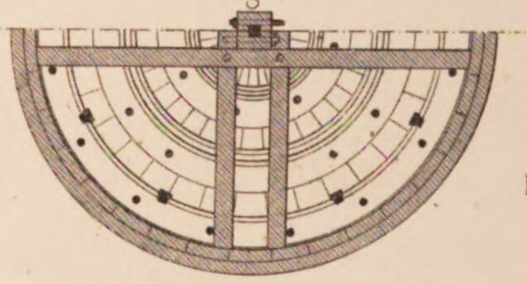


Fig. 2.

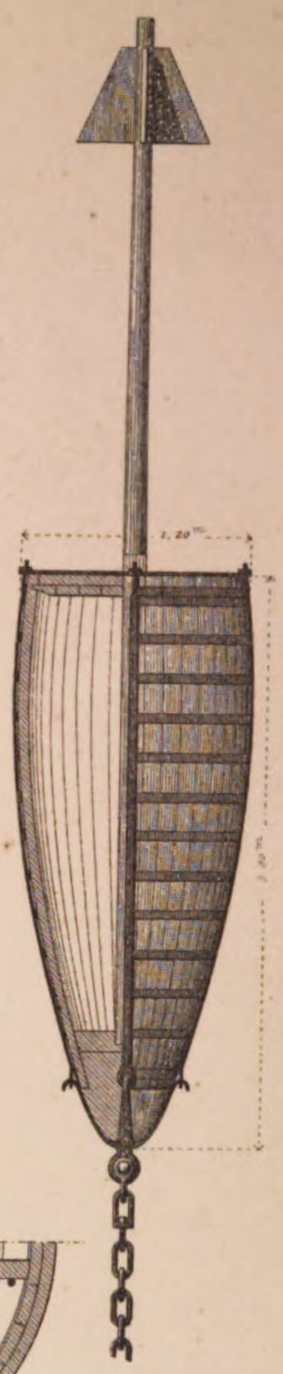


Fig. 7.

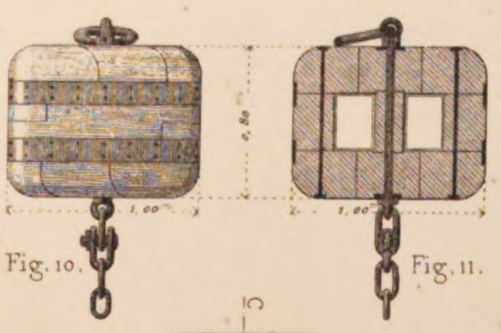


Fig. 10.

Fig. 11.



Fig. 13.



Fig. 15.



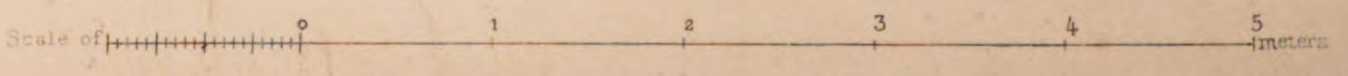

Fig. 9.



Fig. 12.



Fig. 14.




WOODEN BUOYS.

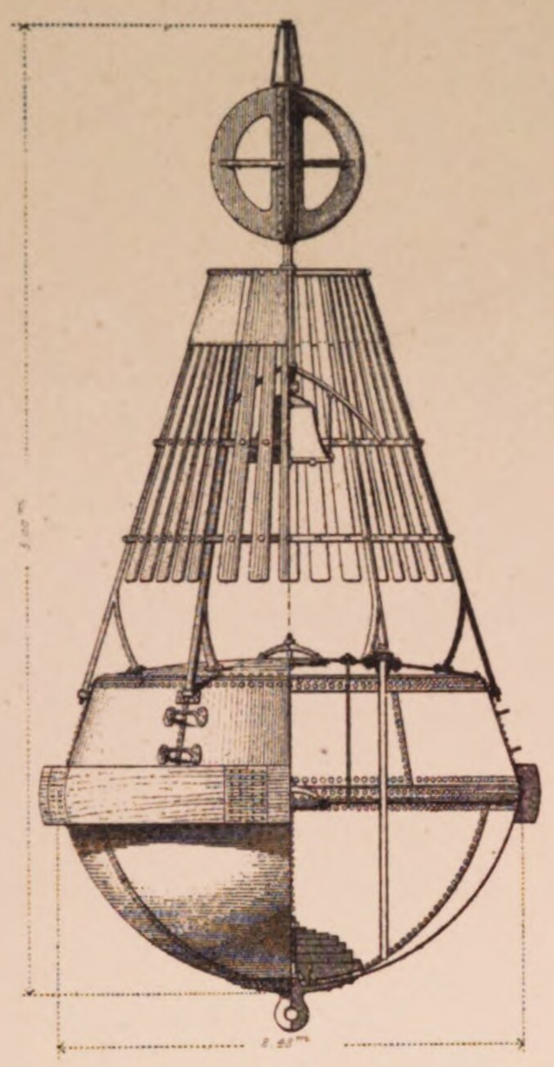


Fig. 5.

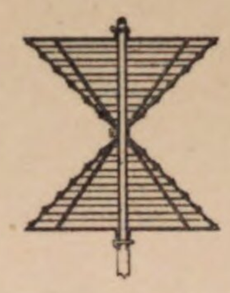


Fig. 11.

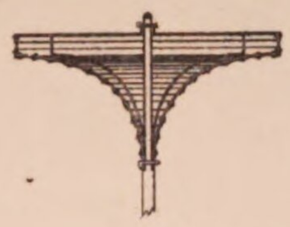


Fig. 12.

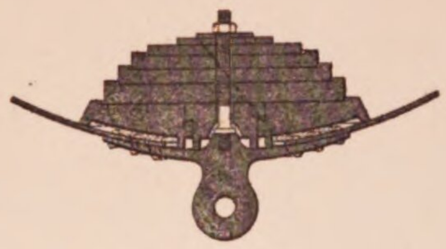


Fig. 3.

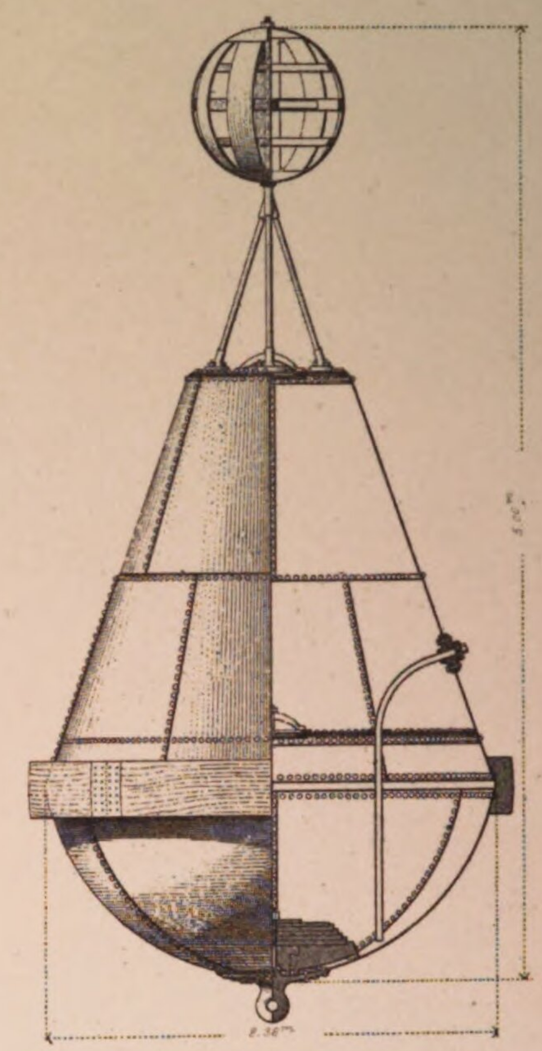


Fig. 1.

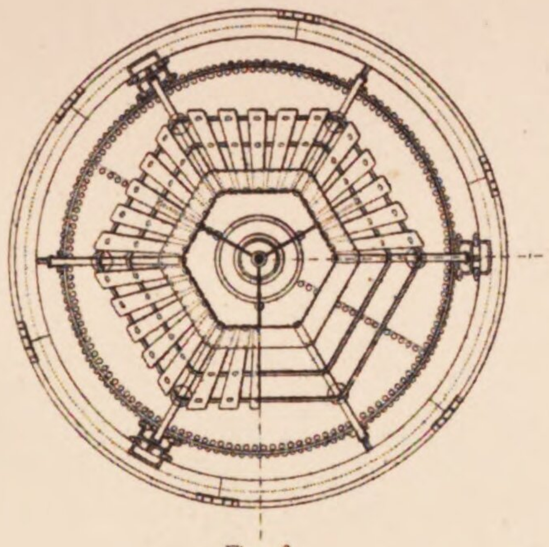


Fig. 6.

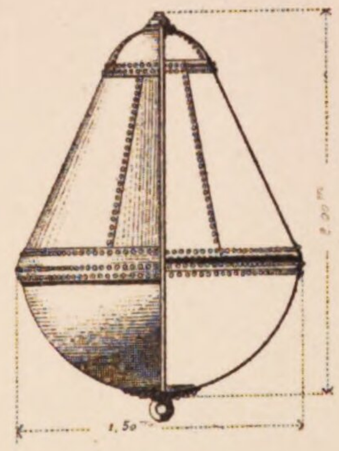


Fig. 4.

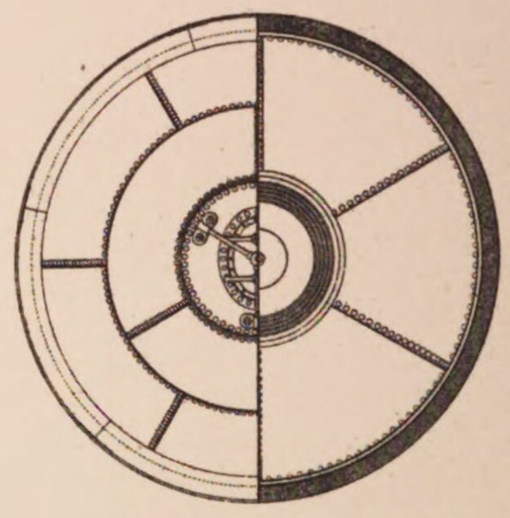


Fig. 2.

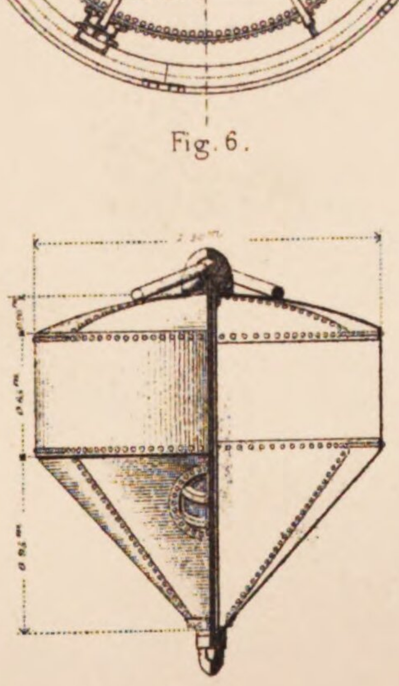


Fig. 7.

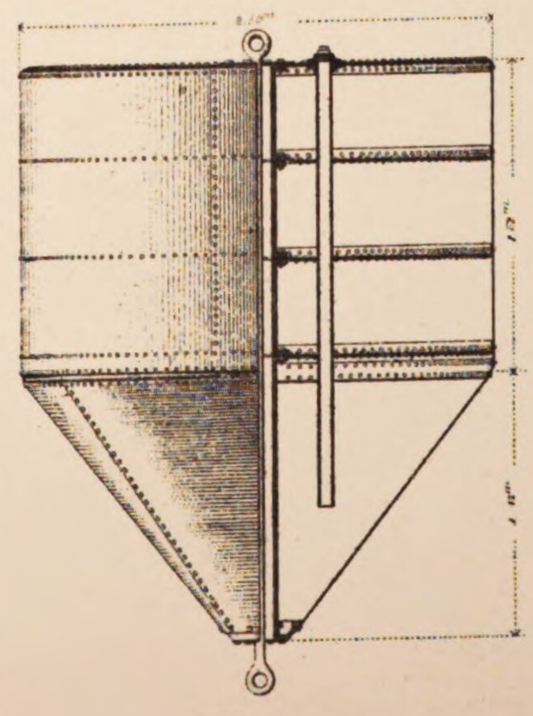


Fig. 9

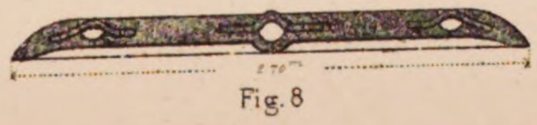
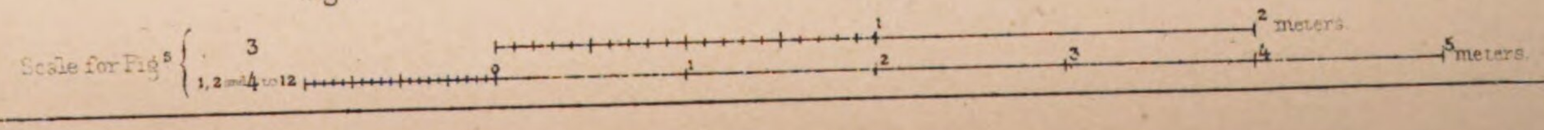


Fig. 8



Fig. 10.




# WROUGHT IRON BUOYS.

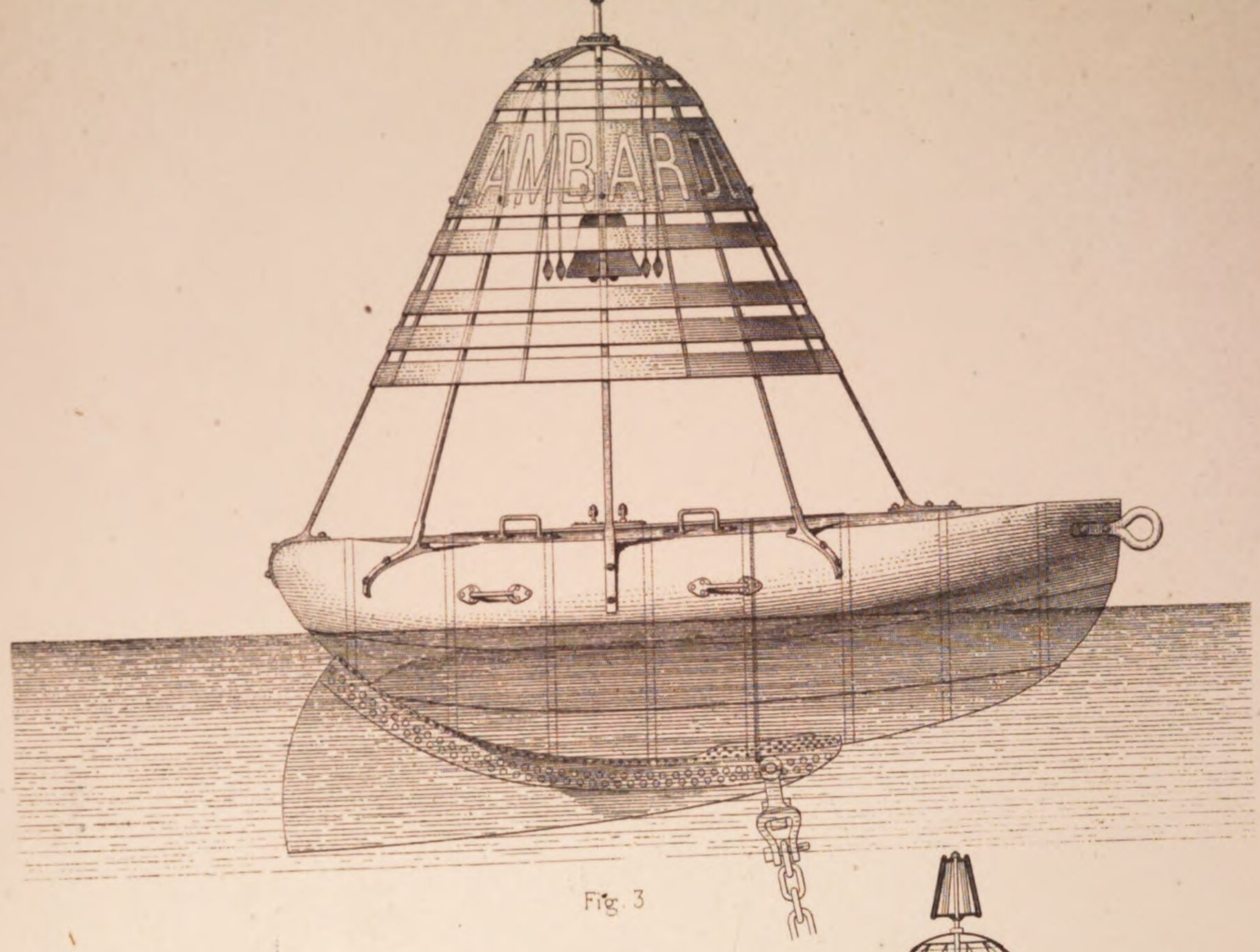



Fig. 3

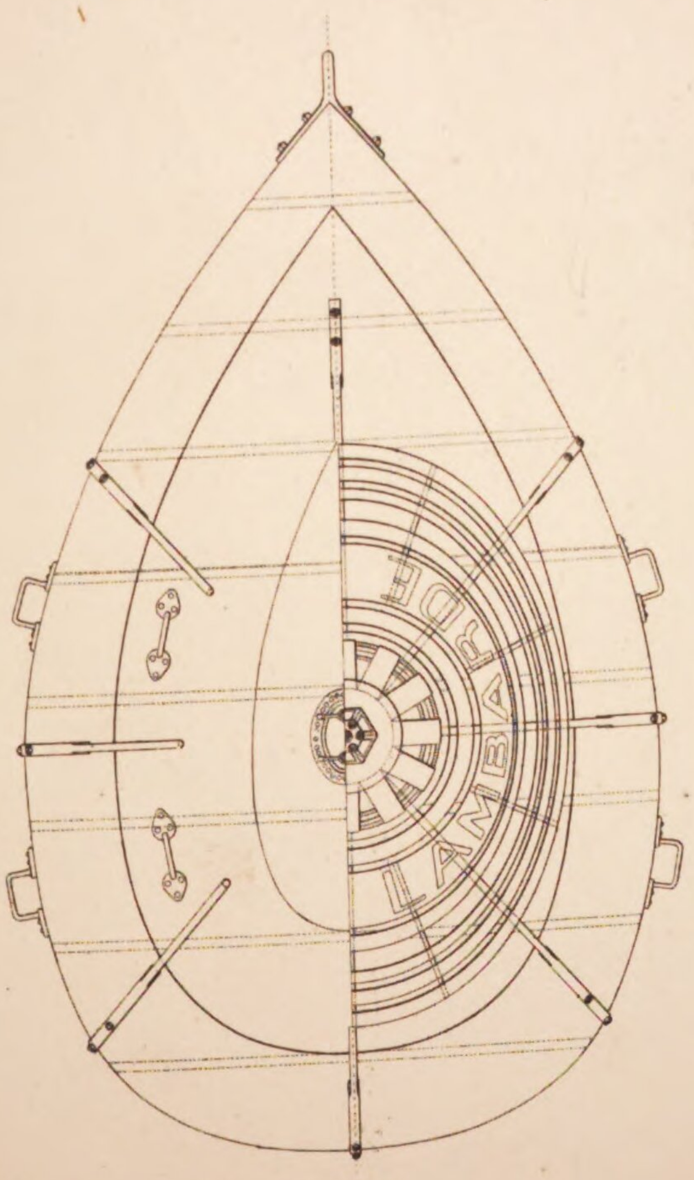



Fig. 1

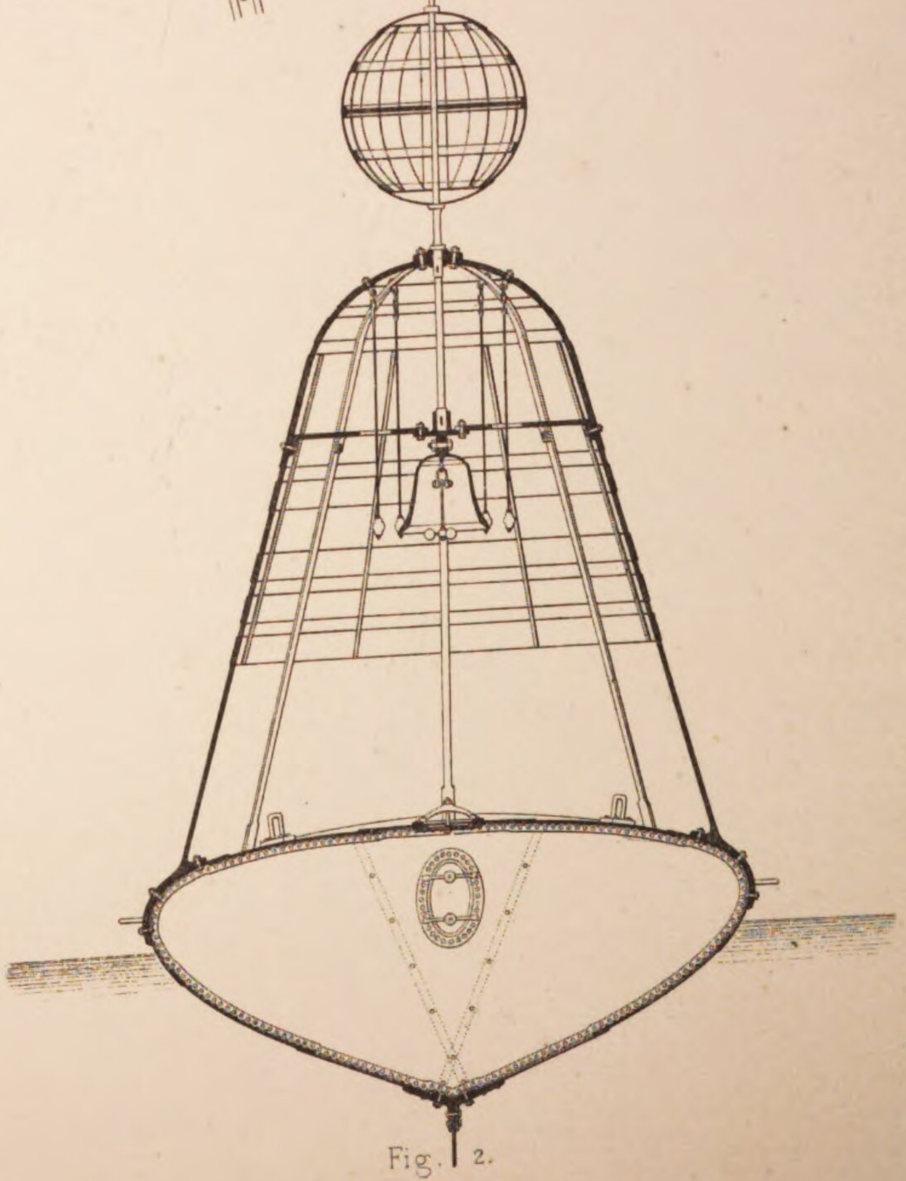


Fig. 2.

Scale of 0 1 2 3 4 5 meters

# WROUGHT IRON BUOYS.

BUCHBINDEREI
VON
AUGUST WERZ
MÜNCHEN

BSB Bayerische StaatsBibliothek
MDZ Münchener DigitalisierungsZentrum Digitale Bibliothek

Reynaud, Léonce

Memoir upon the illumination and beaconage of the coasts of France

Bd.: [1]

Washington 1876

2 A.hydr. 24 q-1
urn:nbn:de:bvb:12-bsb11324965-0